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Contents.

	PAGE
Forthcoming Events	97
Continuous Casting	97
Double Harness	97
Uniform Trade Customs for American Foundries	98
Steel Wages Agreement	98
Britishers to Tour French Foundries	98
Patternmaking and Moulding	98
Random Shots	98
Potentialities of High-Duty Grey Cast Iron	99
Some Developments in Aluminium Metallurgy	101
Mass and Skin Effects in Cast Iron	105
Alloys Now Cast in Great Britain	107
American Production of Centrifugal Cast-Iron Pipe	110
Features of the Cleveland A.F.A. Convention	110
Rust Spots on Iron Castings	110
Trade Talk	112
Personal	112
Obituary	112
Contracts Open	112
New Companies	112
Reports and Dividends	112
Iron and Steel Markets	114
Students' Corner	114

THE FOUNDRY TRADE JOURNAL IS THE OFFICIAL ORGAN OF THE INSTITUTE OF BRITISH FOUNDRYMEN; THE WELSH ENGINEERS' AND FOUNDERS' ASSOCIATION, AND THE FOUNDRY TRADES EQUIPMENT AND SUPPLIES ASSOCIATION.

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Forthcoming Events.

FEBRUARY 10.

Institute of Metals (Scottish Local Section):—Ordinary meeting at Glasgow. "Pyrometry," Paper by S. H. Hawkins.

FEBRUARY 11.

Sheffield Metallurgical Association:—Ordinary meeting. "A Review of the Effects of Cold Work on the Physical Properties of Steel," Paper by F. S. Merrills.

FEBRUARY 12.

Institute of Metals (Swansea Local Section):—Ordinary meeting. "The Corrosion of Non-Ferrous Metals," Paper by A. G. Ramsay, Ph.D., B.Sc.

FEBRUARY 13.

Institute of Metals (London Local Section):—Ordinary meeting. "Temperature Measurement and Control in Works," Paper by H. H. Smith.

Institute of British Foundrymen.

FEBRUARY 15.

Wales and Monmouth Branch:—Meeting at Newport. Discussion on "Training Apprentices," opened by W. R. D. Jones.

Continuous Casting.

The interest in this phase of foundry work continues to increase, and with a better understanding of the subject a number of interesting related problems are coming to light. Generally speaking, British conditions are vastly different from American in that quantities are less, and variety in output must be taken into consideration. The first problem often to be solved is that of a reasonably continuous supply of metal in order to release tackle for re-use at the earliest possible moment. For certain work the cupola, in its smallest sizes, is not so reliable as a good mixer as one would like. Hence a receiver, a storage tank—fired by some external means, or an entirely different type of furnace is suggested. A second problem is whether old, yet very expensive, buildings can be fitted out with a continuous system at a price more favourable than the construction of an entirely new building of a light, cheap, yet effective character. Another problem is that of sand supply. In certain cases all the sand used may be of a "facing" character or a compromise between that and "backing" sand, but for some types of castings there must be a supply of both types. A factor of varying importance is the supply of cores. In some cases this is of paramount importance, whilst in others it can be more or less neglected. If a system could be devised of using green sand cores made side by side with the moulds a distinct advance would be registered, but in the main such experiments have not met with success.

The correlation of speeds for the various conveyors, with sand consumption, mould manufacture and actual pouring is gradually being evolved, whilst the provision of suitable conveyors associated with absence of vibration where essential can be stated to have been solved.

The installations made or being created deserve all the encouragement that everybody can give—the financial backers, the executive heads, the suppliers, whether monopolistic or competitive, for with unqualified success the prize for all is truly a rich one, and every foundry should take a real interest in the movement now so prominently before them, and ascertain just how far they can participate with advantage.

In the early attempts at mechanisation, the moulder was converted from a sand shoveller and puncher into a porter, whilst now he is being changed into an assembler or closer of moulds. It is the intensive study of this last phase which we commend to the British foundry owner.

Double Harness.

Although the activities of the great joint-stock banks in this country are invested in the eyes of the plain man with immense influence and authority, they are commonly veiled, if not in mystery, at least in strict privacy. Only on the occasion of the annual meeting is this privacy abandoned so that the chairman may make his customary pronouncement. A tradition has been established that makes these pronouncements a matter of more than local interest, if local be taken to mean a direct financial concern in the bank in question. They have, in fact, frequently been accepted by the community as highly authoritative statements on a wide range of financial and economic questions. A year ago, for instance, the Chairman of one of the Big Five, speaking at the annual meeting, discoursed on the general topic of credit and inflation, with such skill that he was hailed as the first interpreter of these mysteries to the man in the street. At the same time, one of his colleagues spoke on more directly practical lines, discussing the significance of credit advances as an index to the condition of trade. It is sufficient at this date to recall the fact that the bank in question, located predominantly in industrial areas, had been called upon to devote only one-twelfth of its credit advances to the whole group of iron and steel, engineering and shipbuilding, described as the heavy industries.

This year, particular importance attaches to the pronouncements of the big banks. Following on a period of heavy speculation there have been extensive and spectacular financial catastrophes at home and abroad, coupled with a series of changes in the bank rate, which have received plenty of publicity. The public eye is upon the world of finance, and the public mind is still a little uneasy. Although, therefore, this year's pronouncements have been in some respects disappointing, it is reassuring to find that their general tone is one of confidence and optimism. The financial difficulties of the past twelve months—to which we have previously referred in these columns—are frankly admitted, especially in so far as they have exercised a restrictive influence on trade expansion. At the same time, we are also assured that such trade expansion has become a reality, that our export trade is improving, and that industrial reorganisation on the right lines is taking place. The following quotation, however, represents the real point of contact between industry and the banks: "It lies with industry to reorganise itself, that not being within the province of the

banks, and provision of capital is of little value unless a business is efficiently organised and controlled. If the banks should advance further money at a time when the control of the business itself was inefficient, or if the industry as a whole was labouring under more or less permanent difficulties, natural or artificial, which could not be overcome . . . no benefit would accrue, either to the industry or to the banks." It is no new thing for us to be told that reorganisation and increased efficiency will solve our problems, but it is less usual to be told so by the banks and to have the telling accompanied by something in the nature of an offer to do their share if we will do ours. Industry cannot get very far without the banks, but it is at times encouraging to remember that the banks cannot get a great deal further without industry.

Uniform Trade Customs for American Foundries.

The "Iron Age" states that, with a view of securing the formation and adoption of a uniform code of trade customs and sales agreements that would apply to the entire foundry industry, a comparison of foundry trade customs and sales agreements recently was made by the board of administration of the Ohio Foundries Association, Inc., Cleveland, U.S.A. Copies were sent to every foundry trade association in the country, together with a questionnaire asking for an expression of opinion on the adoption of uniform trade customs. Replies indicate that it is the consensus of opinion that uniform trade customs would be a benefit to the entire industry.

The board of administration of the Ohio association decided some time ago to inaugurate this movement. It felt that its members, including foundries making all kinds of castings, needed a set of uniform trade customs. The comparison indicates that there is very little difference in the various trade customs now used by the foundry associations, and that it would not be a difficult matter to set up a uniform set of trade customs. It is planned to hold a conference on this subject. The advice and comments of all trade association executives will be asked, and it is expected that something will be accomplished toward the adoption of a set of uniform customs. The National Association of Purchasing Agents has reported favourably on the plan, and its iron and steel committee now has the matter under discussion. It is hoped that the benefit of the viewpoint of this committee will be secured in formulating uniform trade customs.

Steel Wages Agreement.

An important conference between representatives of Messrs. David Colville & Sons, Limited, and delegates of the men, over a wages agreement was held in Dalzell Steel Works, Motherwell, on January 30. In general the new arrangement affects practically all the workers except tradesmen, and some thousands of workers are involved. Bonuses and other temporary payments to lower-paid men on tonnage rates will be given a more permanent form. There is an all-round adjustment of tonnage rates, allowing for a levelling up of the wages of the lower-paid men. The melters have raised some objections to the scheme, but it is expected that the difficulties will shortly be overcome. It is hoped that the scheme may come into operation almost immediately.

Mass and Skin Effect in Cast Iron.—Though it was mentioned in the text that the scale for the crushing test was five times that of the tensile test in Fig. 1 of Dr. Swift's Paper, published on page 79 of our last issue, the actual diagram only detailed the figures for tensile.

Britishers to Tour French Foundries.

As previously announced, a party of members of the Institute of British Foundrymen are arranging to spend the week commencing Sunday, March 23, in visiting representative French foundries. The cost for travelling, hotel accommodation, but excluding lunches and dinners, will not exceed £10, from and to London.

The preliminary programme is as scheduled, along the following lines:—

Sunday, March 23, 1930.—Leave London (Victoria) at 2.0 p.m., arriving Paris (Gare du Nord) at 9.0 p.m.

Monday, March 24, 1930.—*Morning.* Visit works of Société Anonyme des Etablissement Ph. Bonvillain & E. Ronceray, Choisy-le-Roi. *Afternoon.* Visit foundry, High School and Arts et Metiers School, Paris.

Tuesday, March 25, 1930.—*Morning.* Visit works of Société Acieries de Vitry (steel foundry) situated at Vitry, near Paris. *Afternoon.* Visit works of Renault Motor Company or works of Montupet (Société Montupet Aluminium Foundry).

Wednesday, March 26, 1930.—*Morning.* Visit works of Société Citroen (motor manufacturers, foundries, etc.). *Afternoon.* Visit works of le Malleable de la Seine at Colombes, near, Paris, or, alternatively, the Bronze Art Foundry of the famous firm of Barbedienne.

Thursday, March 27, 1930.—Leave Paris at 8.0 a.m. for Lille, arriving Lille at 11.0 a.m. Visit works of Massey-Harris Company, at Marquette, near Lille, and also the works of the International Harvester Company at Lille.

Friday, March 28, 1930.—Leave for Boulogne at approximately 9.0 a.m. *Afternoon.* Visit works of Société Paris-Outreau (steel foundry), situated just outside Boulogne. Depart for England by boat leaving Boulogne Maritime at 7.0 p.m., arriving London (Victoria) at 10.47 p.m.

Patternmaking and Moulding.

At a meeting of the London Junior Section of the Institute of British Foundrymen held at the offices of The Foundry Trade Journal on Friday, January 31, Mr. J. D. Hotchkis gave an interesting talk on "Patternmaking and Moulding."

He emphasised the importance of the foundryman and patternmaker putting their heads together before a job was commenced in order to decide the best way of making it. Only by such co-operation was it possible to carry out the work efficiently and with the least possible trouble to all parties concerned.

The lecturer described methods of doing various jobs, including locomotive funnels, illustrating by means of blackboard sketches what were, in his opinion, the best methods. He pointed out the advisability of allowing as much taper and draw on the pattern as possible in order to ensure getting a good sound casting. The chairman (Mr. H. R. E. Slater) proposed a vote of thanks to Mr. Hotchkis, which was heartily responded to by all present.

High-Duty Cast Irons.—Owing to a printing error, the nickel percentages in samples numbered E-2, F-5, G-8, H-13 and 1-14 of Table I of Mr. McRae Smith's Paper, printed on page 84 of our last issue, were shown as chromium content. The details of the mixtures, however, indicated clearly that these were nickeliferous cast irons.

Random Shots.

There came my way this week a cutting, now nearly a decade old, from one of our veteran popular weeklies. It was headed, in the usual instructive manner of journals of that type, "How Moulders Mould." My friend the Editor tells me that, at the time, the article was actually reprinted *in extenso* in the columns of The Foundry Trade Journal, but there must be plenty of readers who, like myself, have forgotten it in the press of weightier matters. And as it is far too precious a gem to go unnoticed by such as you, O most appreciative readers, I give it herewith.

* * *

"It is because the moulder casts, or moulds, hundreds of thousands of small parts of machinery required by a variety of trades that the recent strike threatened to paralyse industry."! So begins our authority, referring to the celebrated moulders' strike that founders have not yet forgotten. Then he gets into his stride: "His work consists mainly of pouring liquid iron into moulds prepared for him by patternmakers, but considerable skill is required in using the moulds and turning out the metal parts required.

"In most of the big foundries there is a patternmakers' department, the moulders being roughly divided into two classes—ordinary moulders and 'core-makers.' For pipes and other tubular things a double preparation is necessary, for a core must be put in the centre of the pipe-mould to keep the passage clear. The cores are made of clay and dried in furnaces, and sometimes wrapped in straw. The hot iron burns off the straw, but the straw keeps it from sticking to the core. If many castings are required a brass or iron mould is prepared."

* * *

At this point I feel like offering a prize for the most complete list of howlers—it reminds me of the composite pictures of one's childhood: "What is wrong in this picture?" However, there is more to come. "It is the moulder who, as he pours the hot iron into the moulds, has to keep them in position, so that the pattern is turned out exactly as required. This is done with the aid of damp, green sand which he banks round the moulds, or boxes, which are clamped to maintain their stability.

"One of the most interesting sights in the moulders' shed of an iron foundry is to see the workmen carrying the molten metal from the furnaces to the casting beds in clay-lined pots swung on a lever. When a great quantity of metal is required it is carried along by means of an overhead trackway from which the pots are suspended."

* * *

I wonder if there were any moulders among the readers for whom this tit-bit was intended, and if so, what they thought about it? It reminds me of the unfortunate author of an article on pewter in a provincial paper recently—I didn't see the original, only the subsequent correspondence—who rashly referred to the unpopularity of pewter vessels for food on account of its lead content. The paper was promptly inundated with letters from makers of pewter, users of pewter, experts on pewter, and so on, denying the presence of lead and generally putting in his place the would-be authority!

Marksman.

Potentialities of High-Duty Grey Cast Iron.

Following Mr. A. E. McRae Smith's lecture to the London Branch of the Institute of British Foundrymen, a number of well-known foundry metallurgists contributed their views to this interesting subject. The discussion was opened by MR. JOHN SHAW, who said that Mr. Smith's Paper was particularly valuable because it was based on practical experience and gave results which one could test for oneself. Mr. Smith had advocated steel mixtures, and had put forward tentatively the theory that the advantage derived from the addition of steel to ordinary cast iron was due to the lack of graphite nuclei in the melt. There was much circumstantial evidence in favour of that, and he (Mr. Shaw) and many others had accepted it to a great extent as being the only feasible theory, but it would be very difficult to prove. He was also pleased the author had made such a point of cupola control when using these high-steel mixtures. Even with the best control it was hardly possible to keep carbon within wide limits, as a glance at the tables published in connection with the "Emmel" process would show. Turning now to Table I, whilst the various compositions and tests given were very valuable, as showing which iron would stand up to pressure tests, in various sections—a subject in which Mr. Smith was very interested—as an indication of the ultimate strength of a casting, they were misleading. In the first place, it is not probable that the weakest iron, C6, would contain in the same casting such variations in thickness in main sections as 1 in. to 5½ in. Perhaps at the junction of several ribs or large bosses it might occur, but these would be taken care of by denseners and the structure modified. If such a casting had to be made, Mr. Smith would be the last man to use composition C6, but would stiffen it up and allow for the annealing effect of the thicker sections on the thin ones. Secondly, if such a casting were made, the 5½ in. thick section would not be machined down to 0.564 in. thick. How this effected the test result was apparent when one compared the test figures from the centre and outside of the 5½-in. bars. When one realised the much greater area of the outer portion of the large bar compared with the centre, and also took into account that the test result of the bar taken from the outside was probably low, due to the inner soft side throwing the bar out of alignment under full load, it was probable that 10 tons per sq. in. would be about the figure if the bar was tested full size. Granting that a casting with main scantlings varying from 1 in. to 5½ in. thick was cast from composition C6, the 5½ in. thick portion, even reckoned at 6.2 tons per sq. in., would be thirteen times as strong as the 1-in. section, reckoned at 14.6 tons per sq. in., and the failure would be in this latter section and not in the thick section. (Area of 1 in. dia. at 14.6 tons = 11 tons. Area of 5½ in. at 6.2 tons = 147 tons.) He purposely stressed this point, because there was a grave danger that engineers reading the low figures taken from the centre of a large bar were misled and the reputation of cast iron suffered. These great differences in section of a casting were rarely added for strength alone, their principle function being to impart rigidity to the machine, so that wear in the moving parts could be reduced, by keeping the machine in constant alignment and to prevent vibration. He expected Mr. Smith to say more about pearlitic structure iron, and he brought three slides taken from some work done by Allen, of the American Car Wheel Company. These micros., taken at 2,000 dias., showed clearly the variation it was possible to obtain, that accounted to some extent why one could have tests from 9 tons to 18 tons in a casting showing an all-pearlitic structure. Mr. Smith had mentioned several times certain irons gave better wearing qualities. If he could indicate how he arrived at this conclusion or what test he applied he would place many founders in his debt.

MR. SMITH said he had purposely refrained from dealing with that subject in the Paper because it was one about which we knew very little.

MR. SHAW (proceeding) said he had raised that question because of its general interest. He passed round two sections of piston rings, together with relative micros. (Figs. A and B). These rings were taken from the same piston, the analyses were identical, yet one wore four times as fast as the other. He had little hesitation if, after examination of the two micros., the members were asked which gave the best wear, nine out of ten would decide, and reasonably so, for the finer graphite structure ring. Yet the contrary was the fact.

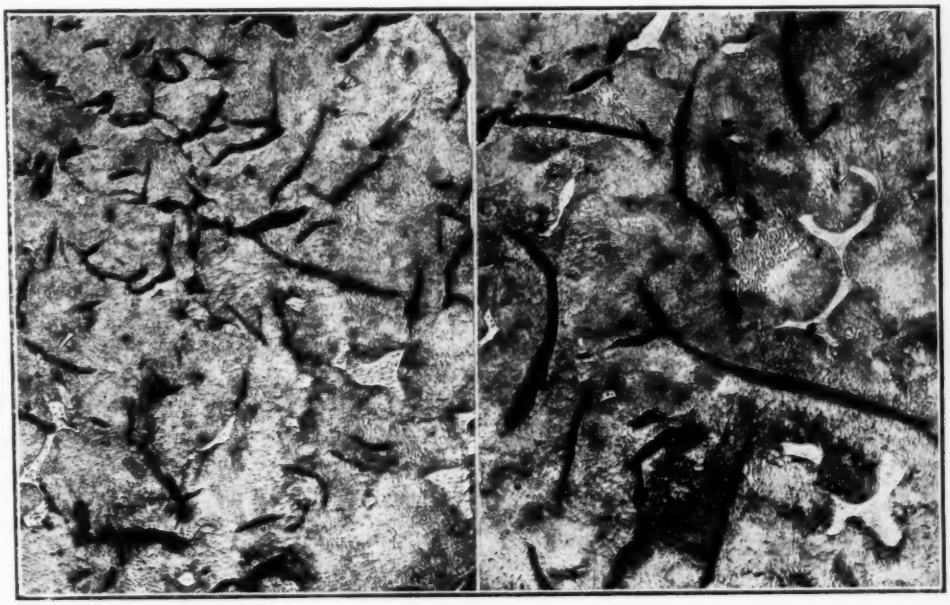

FIG. A.—PISTON-RING METAL. × 200.

FIG. B.—SIMILAR METAL TO FIG. A, YET WITH INFERIOR GRAPHITE STRUCTURE, WORE MUCH BETTER.

Finally, he expressed gratitude to Mr. Smith for having emphasised so strongly the importance of producing castings consistent in their qualities, because foundrymen were troubled, not so much in obtaining irons which would give high test results, but rather because of the variations in the qualities of castings of similar nature.

Pig-Iron Specifications.

MR. C. CLEAVER suggested that Mr. Smith had been rather lenient with the pig-iron makers when he had referred to the variation in the percentage of silicon ranging from 2.7 to 3.3 per cent. That represented a difference of approximately 30 per cent., and, unless there were more consistency in this respect, the founders would have difficulty in producing the correct mixtures. He asked if Mr. Smith would be willing to divulge his method of producing the 50 per cent. steel mix. Did he use ferro-manganese, and did he use a special cupola? Referring to Table I, he said there was quite a similarity between the test results on the mixtures D4 and L11, though apparently the D4 mixture contained ordinary pig-irons, whereas the L11 mixture contained 20 per cent. of steel scrap and additions of nickel and chromium. The test results, particularly those relating to the larger sections, seemed to indicate that no advantage was to be derived as the result of incurring the additional cost involved in producing mixtures such as L11. Indeed, the test results on the heavier sections made of the D4 mixture seemed to be rather better than those obtained on the L11 mixture.

Shock-Resisting Properties of Perlit.

MR. W. J. MOLYNEUX asked if Mr. Smith had had experience of superheating cast iron before casting—to 25 or 30 per cent. superheat in the neighbourhood of 1,600 deg. C. He himself had been carrying out experiments recently with iron superheated to that extent. The test results obtained with Lanz Perlit iron, as given in the Paper, were very largely in accordance with his own results, though his experience with Lanz Perlit iron was perhaps rather more limited than that of Mr. Smith. One of the most valuable properties of Lanz iron, in his view, was its shock-resisting properties, but one could not appreciate it by tensile, transverse or almost any other test. Finally, he asked for further information as to the qualities of the nickel-chrome series of cast irons, and particularly with regard to their wear-resisting properties.

The Test-Piece Problem.

DR. A. B. EVEREST said that a great deal of attention was now being given to the problem of producing truly representative test-pieces, and in connection with the tests discussed by Mr. Smith it was of great interest to note that in the United States they were talking of a specification, for locomotive cylinders, providing that a test-bar was to be cast 4 in. in diameter and the tensile strength determined on a bar, machined to about 0.798 in., from the centre of the casting. He took exception to Mr. Smith's remarks concerning the grading of cast-on bars, because, in his opinion, cast-on bars were almost less representative than separately cast bars. With the latter one had a standard measure of the mixture, if cast under standard conditions, and one could compare one mixture with another. In the cast-on bar, however, there was the mass-effect of heat from the casting itself, and that must be very carefully standardised if the bar were to mean anything at all. If a bar were cast on stilts on the casting, and the stilts were 3 in. long, the bar would give different results from those obtained from a bar cast on stilts 6 in. long. It actually gave re-

sults mid-way between those of the cast-off bar and the actual casting, but how far those results differed from those of the casting itself or those of the separately cast bar depended entirely upon circumstances. He believed the separately cast bar would give the most consistent results.

Nickel Additions.

Commenting upon Mr. Smith's complaint that the addition of nickel to iron in the ladle was not altogether satisfactory, Dr. Everest said that in general experience such nickel additions had proved satisfactory for nickel up to about 1.5 or even 2 per cent., and he mentioned one well-known foundry in which such methods had been used consistently with satisfactory results, in a particular grade of castings, over a period now of 18 months. The nickel iron appeared to run well, and, indeed, Mr. Smith had said that nickel iron appeared to have a better fluidity than ordinary iron. He (Dr. Everest) believed that to be so. If one added nickel shot outside the furnace the iron was chilled a little by the melting of the shot into the iron, and yet practical tests had shown throughout that the nickel iron would run just as easily as would the ordinary iron, in spite of the slightly lower temperature of the nickel iron; so that, if one passed the nickel through the furnace, it was quite logical to expect a better fluidity for a given temperature in the nickel iron than in the ordinary iron. Viscosity had something to do with it, of course, but possibly the freezing range was of more importance.

Nickel-Chrome Cast Iron.

The opinion arrived at by Mr. Smith, in connection with additions of nickel and chromium, that the chromium was not of very great benefit, was entirely in accordance with his own opinion. In this connection, Dr. Everest discussed the densening of heavy sections of open, low-strength structures with a view to improving their strength, and particularly to overcome porosity. A definite silicon content, he said, gave a certain strength. If one added nickel and chromium, there might not be very much improvement in strength, and, similarly, there would not be very much improvement from the point of view of porosity, so that the two things were linked up. On the other hand, if one could reduce the silicon first, and then add nickel, the result was a very great improvement in strength and pressure tightness. Finally, referring to the machinability of irons of high Brinell hardness, he said that one firm in the North was making nickel cast iron—and had gone so far as to give it a trade name—and the standard aimed at by that firm was a Brinell hardness of 260 in castings which must pass through the machine shops. This material was found to have extraordinarily good wearing qualities.

Casting Properties.

Mr. H. C. Dews complimented Mr. Smith particularly upon the fact that he had emphasised the importance of the casting properties of the irons dealt with—a factor which was emphasised too seldom in lectures and Papers dealing with high-duty cast irons. Mr. Smith had stressed the fact that some of the high-duty cast irons, built up on more or less theoretical considerations, did not cast well, and that was a fact that the practical foundryman very frequently discovered to his cost. In particular the addition of a high proportion of steel in the cupola, to the extent of 50 or 60 per cent., gave trouble in the foundry, unless the composition of the iron was very carefully balanced in accordance with the proportion of steel added. There was shrinkage trouble especially, which was very difficult to account for otherwise than by reference to the addition of the steel, although test-bar results showed that the strength of the iron had been increased very much by adding considerable proportions of steel. A problem which was worthy of attention from people with facilities and experience such as were possessed by Mr. Smith, was that of producing an iron as strong as one made with 60 or 70 per cent. of steel in the mix, but yet without the foundry troubles attendant upon a high proportion of steel and without using expensive alloy additions.

Critical Phosphorus Content.

Referring to the details of the irons listed in Table I, he asked what particular object Mr. Smith had in view in choosing a phosphorus content of about 0.5 per cent., because in his experience that was a very troublesome percentage in most cases, and usually one could obtain better results by using percentages of phosphorus very much lower or very much higher than 0.5 per cent.

AUTHOR'S REPLY.

Mr. McRae Smith replied to the discussion. Dealing with Mr. Shaw's remarks concerning the size of test-bars, he said he agreed to a certain extent, but if one were comparing bars from 1 in. to 5½ in. diameter it was necessary to make the test-bars properly comparable. It was rather difficult to get a satisfactory 0.798-in. bar out of a 1-in. bar, and in order to make the test-bars comparable he did not see how one could do anything else but use 0.564-in. bars, unless one adopted 1½-in. or larger casting diameters and used 0.798-in. bars. He was in favour of the 0.798-in. bar, and often used it for ordinary routine testing in the foundry. At the same time, the purpose of Table I was to show what were the internal strengths of the bars, leaving out altogether the skin effect. With regard to the 1-in. scantling, with the 5-in. lump cast on, from the designer's point of view he agreed that the 5-in. lump would be sufficiently strong, but if we could obtain a cast iron in which the strength all through was more nearly equal, then in many cases the lump need not be anything like so big, and the foundryman would be freed of a good deal of the casting troubles which arise from diversity of section.

Uniformity of Perlit.

Commenting on the slides of pearlitic irons, shown by Mr. Shaw, he pointed out that most of the irons mentioned in Table I, with the exception of B.3, C.6, D.4, and to a certain extent A.1, were pearlitic all through, but the sizes of the graphite and pearlite lamillæ were entirely different in the different irons. The Lanz Perlit iron was pearlitic all through, but had big grains, and the big grains persisted in very diverse sections. As to wear, he had left it out of consideration, because he had stated that foundrymen were called upon to supply irons with improved wear-resisting properties; he had not said that he could produce them, for the reason that he did not know what was meant by "wear," and did not think anybody else knew either. Referring to the piston rings mentioned by Mr. Shaw, he said it was important to consider what happened during the first few hours' work after the piston rings had been fitted to a piston. Very often a casting such as a cylinder liner might show considerable deterioration during the first few hours of running of the engine, but once a cylinder liner had stood up to its work satisfactorily for that first short period it would usually continue working for years without disturbance.

Pig-Iron Purchase.

Replying to Mr. Cleaver, he said he did not consider he had been lenient with the pig-iron makers. His statement in the Paper was to the effect that if one wanted an iron to a very close specification one should call for it, but if one wanted iron for a common purpose, and to a loose specification, then one should adopt a loose specification and obtain the iron at a lower price in consequence. As to his method of producing the 50 per cent. steel mix iron, he said there was nothing in it. He had given the particulars of the mixture in sample A.1 in Table I. The 10 per cent. of Burn pig-iron was bought at a moderate price; it had a fairly high carbon content, and was a sort of stabilising iron. The Northants iron was quite a common one, containing from 5½ to 6 per cent. silicon. He bought the cheapest steel scrap he could find, and rather lumpy in character. He liked rail-ends and girder-ends if he could get them, but it was not always possible to get them at an economic price. Pieces of steel cut up at the cement works in the district were also bought, for it had to be transported only short distances, and the steel scrap from his company's engineering works was also used. He had no difficulty in bringing down pieces of steel up to 3 cwts. in weight in a 6-ton cupola, but if thin sections of steel were charged into the furnace there was difficulty due to oxidation. Ferro-manganese was added in massive form direct to the cupola. Discussing Mr. Cleaver's comparison of the samples D.4 and L.11, he said that in the few tests he had made the nickel-chrome irons did not show up to the same advantage as the nickel low-silicon irons.

Replying to Mr. Molyneux, he said he had no experience of superheating to 1,600 deg. C., but was of opinion that cast iron could be improved by superheating. As to the Lanz Perlit iron, he recalled that Mr. Molyneux had been for some time foundry manager for a firm who were licensees for Lanz Perlit iron, so that he had had considerable experience, and had produced some very good iron by that process. Inasmuch as it was made in a hot mould, it was very tough, and had greater resistance to shock than had ordinary cast iron.

Dealing with Dr. Everest's remarks concerning cast-on *versus* cast-off bars, he said that what he objected to was that very often a 1-in. square bar was cast within 1 in. of the side of a massive casting, and that he regarded as ridiculous. In his view we ought to standardise entirely separately-cast bars, but there must be some regulation of standard section, according to weight or mass. If we used cast-on bars there should be some regulation of size or diameter of the test-bars and the length of the runners, *i.e.*, the bars should be a definite distance from the main castings in each case. As to the addition of nickel to iron, he said he had added quite a lot of nickel to the ladles, but had found it much more convenient, when making ordinary nickel iron, to put the nickel straight through the cupola, and he had intended to make that clear in the Paper. He emphasised that the mixtures of which he had given particulars—apart from one or two, which were freak mixtures—were really standard mixtures which were being used in his foundry regularly, perhaps not every day, but as often as twice a week.

In reply to Mr. Dews, he said there had been considerable controversy as to the 0.5 per cent. phosphorus content, but he had never found that the 0.5 per cent. phosphorus irons were any worse than, say, irons containing 0.2 phosphorus. He had purposely chosen a phosphorus content of round about 0.5 per cent. for most of his mixtures in order to see what the results would be. Finally, he agreed as to the importance of soundness, and said it was of no use putting forward strong irons which did not cast soundly. If one ensured the correct relation between the silicon and total carbon contents one could produce, even with a mix containing 50 per cent. of steel, irons which could not shrink excessively.

On the motion of Mr. V. C. Faulkner (past-President of the Institute), seconded by Mr. A. S. Beech, a hearty vote of thanks was accorded Mr. McRae Smith for his valuable Paper.

Mr. C. A. Hadley read a Paper on "Modern Improvements in Electric Resistance Welding Machines", before the Institution of Welding Engineers on Thursday, January 30.

Some Developments in Aluminium Metallurgy.*

By N. C. Ashton.

Among the many difficulties encountered during the melting, pouring and casting of aluminium alloys, it is considered that unsoundness, due to the presence of dissolved gases, the lack of proper fluidity and feeding are the main difficulties. The other troubles—namely, cracking, hot-shortness and development of surface fissures—are very prevalent with certain types of alloys. These combined difficulties can account for quite 80 per cent. of the wasters commonly encountered in general foundry castings. They are essentially relative difficulties, as in most foundries the operators are familiar with either iron or brass founding. They are due to certain inherent properties of this type of metal and cannot be altered. This also applies to the high liquid shrinkage and extreme liability of aluminium to dissolve furnace gases during melting.

Their ill-effects can be greatly reduced, however, and, in some cases, entirely eliminated, and this subject constitutes the object of this Paper.

Under normal conditions, liquid aluminium alloys, when passing into the solid state, will show a shrinkage of from 4 to 6 per cent., according to the pouring temperature. By bad melting conditions, undue contact with furnace gases, by stewing in the pot and too frequent stirring, it is possible to saturate the metal with gas and completely counteract the liquid shrinkage. It is also possible to supersaturate an alloy to such an extent that it will rise like bread when cast in an open mould (Fig. 1). When the metal is being degassed with chlorine it is possible to draw off samples which exhibit all the known degrees of saturation. As degasification proceeds the surface of sample ingots gradually subsides until only a slight surface exudation takes place. This action is similar in appearance to the well-known tin-sweat seen on the runner of a bronze casting. Finally, a stage is reached when the metal shows a very marked shrinkage cavity in the centre of the ingot. If the metal immediately below this cavity or pipe is quite sound, then it can be safely concluded that the metal is gas free (Fig. 2).

In the foundry the apparent feeding and mould-filling properties are very much affected by the amount of gas present in the metal. Using an alloy which in the first instance is gas-saturated, the resultant casting appears to be good, and, on examining the feeding head, it will be seen to be comparatively flat; the inexperienced would say that the metal feeds well and has not much shrinkage. When this casting is followed through the machine shop, it is soon noticed that it is a mass of pinholes (Fig. 3). If returned to the foundry as a reject its connection with the flat runner head is probably not realised.

Using the same alloy, in the second instance completely free from gas, a deep pipe is seen in the runner, and, if the gates are not properly proportioned, a draw will be found somewhere in the casting. In this case, the inexperienced would say that the metal draws badly and has much shrinkage. Actually, in this second instance, the good parts of the casting are very good (meaning quite sound), while in the first

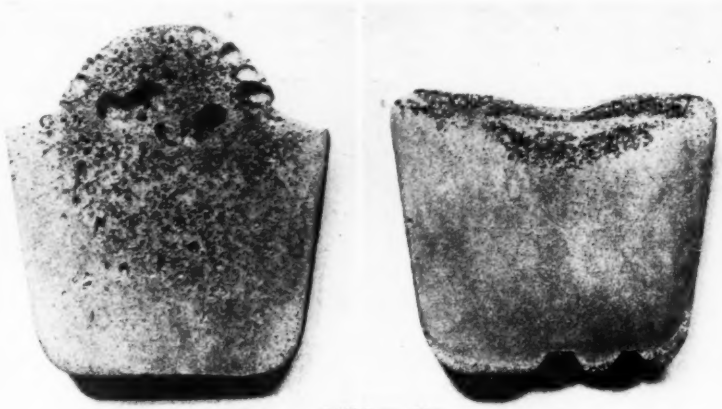

FIG. 1.—METAL AS CAST FROM H.F. INDUCTION FURNACE (*left*), AND AFTER REMELTING AND TREATING WITH CHLORINE GAS FOR 3 MINS. (*right*).

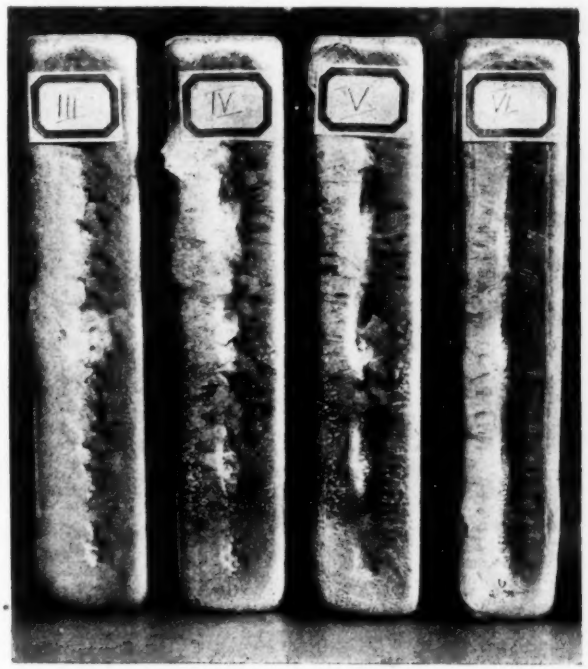

FIG. 5.—UNGASSED, PARTIALLY GASSED, AND COMPLETELY GASSED METAL.

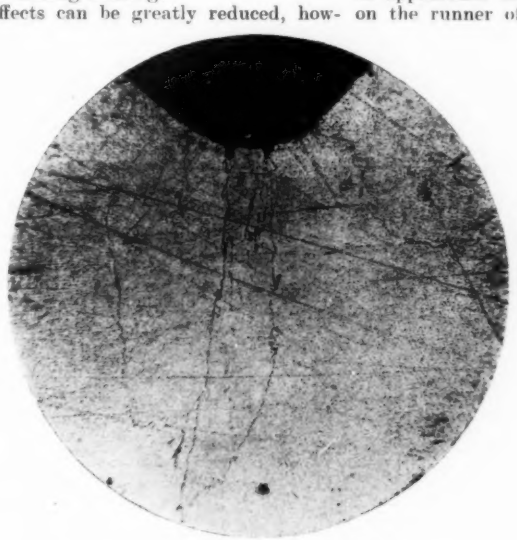

FIG. 2.—SECTION AT BOTTOM OF "PIPE" IN 1½ DIA. CHILL-CAST BAR. × 40 DIA.

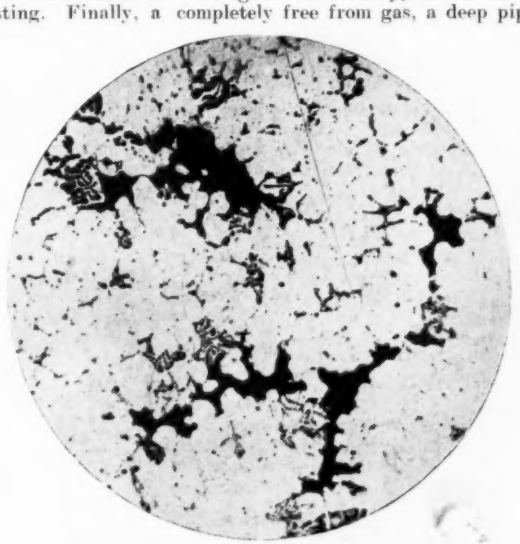

FIG. 3.—UNSOUNDNESS DUE TO CONTRACTION CAVITIES. × 45 DIA.

* A Paper read before the Lancashire Branch of the Institute of British Foundrymen, Mr E. Longden presiding.

instance all the casting is bad and there are no good parts in it.

The remedy for this is obvious, but it requires a great deal more foundry skill to be able to pour a good casting in gas-free metal, which does not show a deep draw somewhere or other. However, when properly carried out, involving the use of denseners and properly proportioned runners and risers, the resultant casting is one to be proud of and may be depended upon in service.

Recent Improvements.

The use of secondary aluminium alloy ingot has increased greatly in recent years, and competition for orders is so keen that in some foundries it is absolutely necessary to use secondary metal. In the methods at present in use for the production of secondary aluminium alloy ingot, no actual refining takes place. The scrap materials, after proper grading, are generally run down to ingots without further refining. In some cases ingot-aluminium additions are made in order to improve the quality of the finished product.

Scrap is available in the form of aluminium sheet cuttings, clippings, domestic ware, etc., as undoubted success and will save up to 40 per cent. of the melting loss obtained with ordinary melting.

A large number of fluxes have been suggested to improve the product, but only a few are in actual use. Their use greatly improves the quality of the resulting ingot, although it may not materially improve the yield of metal. There are solvent fluxes that actually dissolve the aluminium oxide and coalesce the fine particles. These consist mainly of alkaline fluorides, cryolite, etc., and various mixtures. Volatile fluxes, such as the chlorides of aluminium, ammonia and zinc, have a mechanical action on the metal. A good flux should not absorb moisture, must have a low melting point and should not readily attack the crucible or furnace lining. None of the fluxes at present in use can be said to be good on all three points.

Process of Melting Borings.

During melting borings, the pasty mass of metal must be kept constantly moving by proper puddling, largely a matter of skill on the part of the operator. Great care must be taken to keep

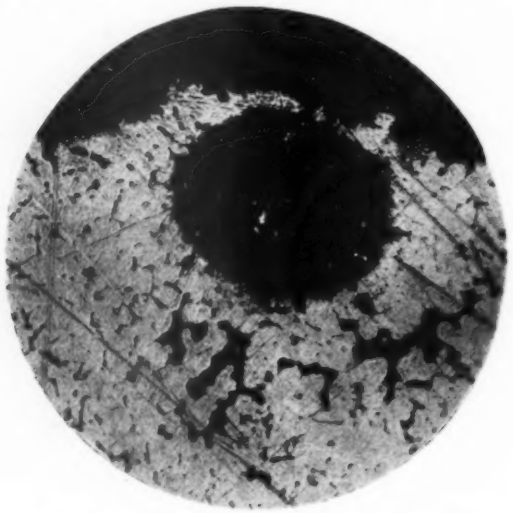

Fig. 4.—Section of Gas Bubble at Surface of Casting, showing Contraction Unsoundness Immediately Below. × 40 dia.

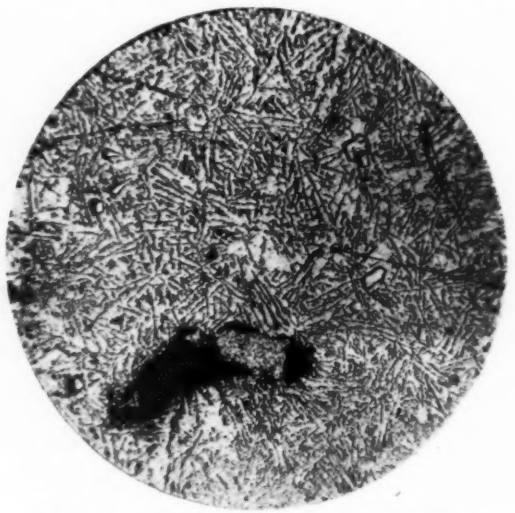

Fig. 6.—Sand-Cast Bar of Stock Alloy. × 40 dia.

alloy scrap castings, chiefly obtained from the motor industry and aluminium alloy borings and turnings. Of these three, the most difficult to deal with are the alloy borings. Remelters generally avoid this type of scrap except where it is necessary to take all forms of scrap from the producers. Impurities in this material, apart from metallic impurities, consist mainly of dirt, sand, alumina, oil, paint, woody fibres and other organic matter. The metallic elements commonly found include iron, copper, zinc, lead, antimony, tin, manganese. The most harmful of these are undoubtedly iron, lead and antimony. Ingots produced from this class of material, besides containing variable metallic impurities, contain much more harmful non-metallic impurities, which are disastrous in their effects on hot-shortness, porosity, cracking and brittleness.

Impurities.

These impurities include alumina, aluminium carbide, aluminium nitride and quantities of dissolved gases, such as hydrogen, carbon dioxide and hydrocarbon gases. The physical properties of an alloy prepared synthetically from the metallic analysis of the scrap ingot, but using virgin materials, clearly demonstrates the difference between the two metals. Treatments, such as centrifuging to remove oil and water, magnetting to remove iron and steel cuttings, will all improve the product, whilst briquetting is an the mass below 800 deg. C. Should it reach this temperature there is little hope of a yield of any consequence, as actual burning rapidly commences, and the only procedure is to exclude air by charging cold dry borings. The thermit-like reaction which occurs is not fully understood, but it is certain that it is primarily caused by the formation of aluminium carbide, which commences to burn, and, in a short time, the temperature is sufficiently high to cause the aluminium to react with the surrounding air, forming alumina and aluminium nitride. That the reaction involves the nitride can be proved by rapidly cooling a portion of the glowing mass, and, when cool, moistening with water, when a distinct smell of ammonia can be noted.

Compositional Specification.

The quality of the secondary ingots is naturally dependent on the scrap that has been used, good-quality ingot should contain at least 80 per cent. aluminium, the iron should not be more than 1.2 per cent., and lead and antimony be not more than 0.5 per cent. Copper and zinc may range from 6 to 10 per cent. each, and silicon should not exceed 1 per cent. The non-metallic impurities, it may be said, are much more harmful than the normal metallic impurities, and generally are not even tested for in the ordinary course of analysis. Of these, alumina is the most common and may be present in amounts up to 1.5 per cent. Carbon, in the form of aluminium carbide, is always present in small amounts of from 0.1 to 0.5 per cent., and so also is the nitride, probably in the same form as alumina. The presence of dissolved gases can be detected by a close examination of the surface of the ingot. During cooling, if gas is present, it can be seen as an effervescence on the surface just at the moment of solidification (Fig. 4). A gas-free ingot is quite smooth and silky to the touch. The presence of carbides and hydrocarbon gas can easily be detected by breathing on a newly made fracture and noting the smell, usually typical of acetylene. Practically all remelted alloys will be found to emit this smell. High-quality virgin ingot and alloys that have been properly refined to remove these gas impurities do not emit this smell.

Most foundrymen hesitate to use more than 50 per cent. of secondary ingot except for low-grade work. Such defects as cracks, draws, porosity and brittleness can be directly traced to the use of too much secondary metal. The use of castings made from unrefined secondary metal mixtures intended to be used as a substitute for brass, bronze or cast iron is to be strongly condemned. Should the castings, owing to their poor quality, break down or show severe corrosion, then it is generally concluded that aluminium alloys are unsuited for the purpose for which they have been used.

The use of secondary aluminium-alloy ingots has greatly increased in recent years, and any method that can be employed to improve the quality will not only result in better business but will also lower the cost of aluminium articles to the consumer.

Apart from the great differences in physical properties between secondary metal and properly made alloys, chiefly in loss of ductility and extreme tenderness in the mould, there is the serious effect of the impurities on the resistance of the alloy to corrosion. It has been found that corrosion may be caused, first by the composition of the alloy, and secondly by the presence of unsoundness, pinholing, etc., easily traceable to dissolved gases. This unsoundness must, therefore, be removed, and much work has been done to this end.

Chlorinisation.

The presolidification method only partially removes the gases, is costly and involves double melting, followed by subsequent risk of re-absorption of gases. A more effective method is that practised also by Archbutt, and consists of passing inert gas, nitrogen,

Fig. 7.—Sand-Cast Bar of Stock Alloy Slowly Solidified and Remelted. × 40 dia.

Fig. 8.—Sand-Cast Bar of Stock Alloy after Four Minutes' Gassing with Chlorine. × 40 dia.

Fig. 9.—12 Per Cent. Silicon Alloy Modified by Calcium. × 500 and × 50 dia.

Fig. 10.—Sodium Modified 9 Per Cent. Silicon Alloy. × 45 dia.

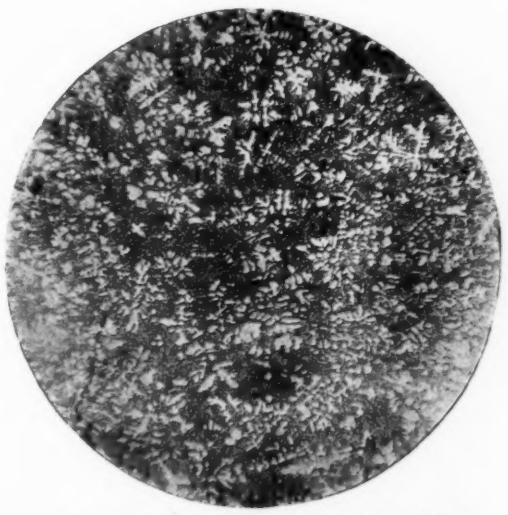

Fig. 11.—Boron Modified 9 Per Cent. Silicon Alloy. × 45 dia.

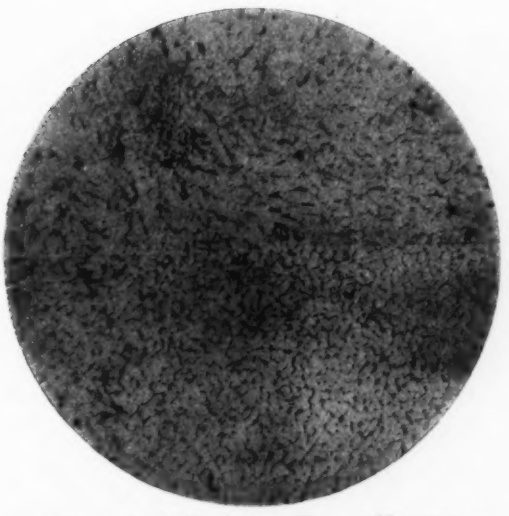

Fig. 12.—E11B Alloy, Boron Modified. × 50 dia.

through the molten alloy with the object of driving out the dissolved gases. A far better method, however, of comparatively recent origin, is to use an active gas that will combine with the impurities. Chlorine gas can be used very effectively for this purpose, as it is recognised to be strongly affinitive to hydrogen and many metals. It is now well understood that hydrogen is present in greatest amount amongst acetylene, nitrogen and oxygen in the form of oxide in the metal. When chlorine comes into contact with these impurities, immediate combination or disintegration occurs, generally with the formation of the chloride. In practice it has been found that the attack is preferential in character, hydrogen and acetylene being most readily attacked.

Treatment is very similar to the Bessemer steel process, except that chlorine is used instead of air. During the process a rise in temperature occurs, and further heating may be dispensed with. As gassing proceeds, a dry, grey-black powdery dross forms on the surface of the metal, which reacts with the air present and which is an exothermic reaction. When this surface reaction subsides and a white powder takes the place of the grey dross, purification is complete. This white powder is almost entirely alumina. The time taken to complete the gassing is from 4 to 15 minutes.

The refining furnace is of special design, lined with a refractory material which is free from carbon or carbon compounds, and which is generally preheated by means of an oil burner. A recent development is to add a catalytic alloy to the metal before treatment so as to upset the equilibrium existing between the metal and the dissolved gases. This phenomena is the chief reason for the unsoundness of "Y" alloy and also the calcium-modified silicon alloys. Both magnesium and calcium will upset this equilibrium.

Short Freezing Range and Soundness.

Test samples, drawn at intervals, and cast during the treatment in open chill moulds, give an excellent idea as to the state of the metal. Prior to the treatment the metal in the sample setting in the mould will give up some of its dissolved gas, and this is easily seen as an effervescence at the surface. At the end of the treatment the surface of the metal is very smooth, bright and exceedingly clean. There is complete absence of unsoundness and there is no cavity beneath the pipe in the ingot. The metal now is quite different in character from the original alloy. It has a shorter freezing range, is more fluid and appears to have a greater shrinkage; really, it has recovered its natural shrinkage.

The refining of borings has been described, as it is considered that their treatment is by far the most difficult so far as melting is concerned and that much more gas is picked up by them in melting. It will be seen that heavy cast scrap, rolled scrap and clean sheet cuttings render it possible to obtain excellent results if they are suitably graded and properly treated. By the use of clean sheet cuttings ingot with aluminium content of well over 99 per cent. is easily obtained.

Grain Size Modification.

Reference to the Paper by Mr. D. R. Tullis in the Proceedings of the Institute of Metals given in September, 1928, on the effects of chlorine on aluminium will give the details necessary for proof of the foregoing. The effects of chlorine treatment are more far-reaching than would be first thought. Since all pure metals—and also alloys, where the constituents are in solid solution with one another—have a large grain size in the as-cast state, then chlorine treatment as it removes the non-metallic impurities causes an *increase* in grain size. Virgin aluminium generally is of large grain, and this tends towards cracking of castings. This explains why it has always been considered beneficial to add scrap, simply because it brings with it impurity which reduces the grain size. Fig. 5, illustrating the grouped ingots, shows that the treated ingots have a narrow pipe towards which there are to be seen large columnar crystals running from the outside of the ingot to the pipe. These surface crystals on the ingot are characteristic of chlorine-treated alloys.

The Effects of Chlorine Treatment.

Extensive tests made on chlorine-treated alloys showed that 65 per cent. were improved by an average of 10 per cent. in regard to corrosion-resisting properties. In the bend test, as an instance of the increase in ductility obtained, 75 per cent. of the alloys were improved by an average of as much as 28 per cent. All tests were cast with the same degree of superheat, both treated and untreated. There is also an increase in specific gravity, which is normally about 3 per cent., but in extreme cases it may be as high as 8 per cent.

The effect on eutectic alloys depends on whether the composition of the alloy lies above or below the eutectic point. If below this eutectic point modification generally occurs, while if above the eutectic point the reverse is the case and the structure is very much coarsened. In one example, sand castings were poured at the same temperature from a stock of 11 per cent. silicon-aluminium alloy which contained a considerable amount of dissolved gases. From this a sand-cast bar was poured at 635 deg. C.; during cooling some gas evolved and the metal was found to be unsound. Fig. 6 shows a micrograph of this bar, with the silicon eutectic in normal form, also some α-compound and unsoundness. Another portion of the stock alloy was melted, slowly solidified in the crucible, remelted and cast, also in sand and again at 635 deg. C. Fig. 7 shows this bar; the eutectic is a little finer in places. A further portion was melted, chlorine gas was passed for four minutes and a sand-cast bar made, as before, at 635 deg. C. The runner head was quite smooth and the specific gravity had risen by 1.2 per cent. over that of the first bar. Fig. 8 illustrates this bar. It will be seen that modification has taken place, although perhaps not so complete as could be obtained with sodium additions.

If the silicon-aluminium alloys are modified with sodium or sodium salts, and subsequently treated with chlorine gas, rapid demodification takes place, and, if gassing is continued for a sufficient time, the alloy completely reverts to a coarse-grained structure. This effect depends principally on the amount of silicon contained and also on the presence of iron. Both the $FeAl_3$ and α-compound increase enormously in size on the addition of a modifier. This is the reason why the silicon alloys must have a low iron-content.

Advantages and Disadvantages of the Chlorine Method.

This process has certain obvious disadvantages when considered from a practical point of view. Chlorine gas is dangerous when inhaled. Even if diluted down to one part in 10,000 in air it has harmful effects. It is necessary, therefore, that great care be taken in its conveyance through tubing, etc. There must be no risk or leakage, and proper means must be provided for removal of excess from the surface of the molten metal. This, fortunately, is fairly easily accomplished. Metal which has been treated by the chlorine method does not require further treatment during subsequent remeltings. It is, therefore, not necessary to have a chlorine plant in every foundry where purified metals are in use.

On account of the fact that metals treated show a marked grain growth, and that this is a serious disadvantage, it has been considered that the process could be further improved. This grain growth results in a change in physical tests of the metal. The yield point is reduced. The maximum stress increases or decreases according to the composition of the alloy. The elongation in every case is improved. In some cases the improvement is considerable and in certain cases is more than doubled. In alloys of high ductility the gain in elongation is not very great.

It may be said here that the process was considerably improved by the use of a gaseous compound, that of boron trichloride. This is, in fact, a low boiling-point liquid. It boils at about 13 deg. C., just below ordinary room temperature. Like the usual type of trichlorides, it is a heavy greenish-yellow liquid, very much reminiscent of chlorine, but as it is a liquid it is much easier to handle in a glass bottle of the soda-syphon type. Releasing the valve of the bottle will allow the dense white vapour to escape, and its effect on the throat and lungs is not nearly so deadly as chlorine. Decomposition only means the formation of boric acid, which is practically harmless, and hydrochlorine acid gas. Since the results of using boron trichloride are very much bound up with the phenomenon of modification, it would be best to go through what is already known about this process.

Modification by Boron Trichloride.

The following definition is given for the term "modification": "When the normally insoluble particles are caused to occur in almost colloidal dimensions." This refers to the eutectic type of alloys, where, of course, the eutectic of the alloy—the last part to solidify—is always insoluble at normal temperature. The elements boron, calcium, lithium, potassium and sodium are known to cause modification in aluminium alloys. The most effective at present in use is sodium. It may be added directly in the form of metallic sodium or it may be added indirectly in the form of sodium salts to the bath of molten metal. If the salts method be adopted, higher temperatures must be used and a sufficient time be allowed for the salts to decompose and liberate the desired amount of sodium. A small, but definite, quantity of sodium must be added in order to obtain proper modification. Should too much sodium be added, "reversion" and "colonisation" will occur. In foundry practice it is very difficult to control effectively the addition of sodium within such very small limits. This is due mainly to the extremely volatile nature of the sodium at the temperatures employed. It is difficult to employ a standard method of making the sodium addition. The amount of agitation of the melt plays an important part in the result. Metallic sodium should be added to the bath of molten metal at a temperature of 700 deg. C. It is not necessary to detail here the addition of the sodium. The metal should be well mixed and allowed to stand for about five minutes before pouring.

The salts method is best carried out by the use of sodium hydroxide, and the metal to be treated should be at a high temperature: 900 to 950 deg. C. is generally necessary. The appearance of the metal is similar to that obtained by the metallic sodium method, but is more liable to be unsound in the casting. The modification produced by both methods is extremely unstable, and the metal must be cooled quickly in the casting in order to preserve the eutectic in a finely divided form. It is not advisable to employ modified silicon-aluminium alloys in castings having a greater cross section than 1 in. thick.

Reversion of Si-Al Alloys.

This method of modification applies solely to the silicon-aluminium alloys; no other type of alloy has been effectively modified by this process. The best results are to be obtained with high-purity alloy of iron content of 0.3 per cent. maximum. Most silicon alloys contain dissolved gases, chief of which is silicon hydride, generally removed during modification. Unfortunately,

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the sodium method of modification does not permanently modify the alloy; it returns to the normal state in remelting and will completely revert on annealing at 500 deg. C. The metal calcium will cause modification in silicon alloys that is more permanent, but it introduces unsoundness to a marked degree. It should be added to about 0.25 per cent. If over 0.3 per cent. is added, the calcium silicide ($CaSi_2$) appears as long flat plates, a source of weakness that completely defeats the effects of modification (see Fig. 9).

Boron Metal as Modifier.

Of recent introduction, boron has been used as a very effective modifier. Owing to the great difficulty of obtaining boron in the pure state it does not always act as an effective modifier, in which case it is necessary to add such quantity that it becomes of non-commercial value. Boron possesses a very marked affinity for both oxygen and carbon. It therefore follows that it cannot be produced from its oxide by means of carbon. An effective process has now been patented to introduce atomic or nascent boron into the alloy during its manufacture, which is a result of improvements made on the chlorine method of refining. It possesses all its advantages, and, fortunately, none of its disadvantages. Chlorine causes an increase in grain size, whereas boron produces a marked reduction in grain size, as much as to 1/3,000th of the original size. The importance of this has already been pointed out. It becomes more important when it can be said that a normally cast alloy which gives 10 to 12 tons tensile and 1 to 2 per cent. elongation will, when fully refined and boronised, give up to 20 tons tensile and up to 8 per cent. elongation without heat treatment.

Alloys, so treated, in order to give a fine grain-throwing capacity will not, under any conditions of remelting, revert to their original coarse grain (Fig. 10). Tests on remelting up to twelve times and heating on each remelt to 800 deg. C. showed only an increase of from 0.2 mm. grain area to 0.5 mm. grain area. Tests carried out on BCl_3-aluminium alloy, after many remeltings and finally heating up to 1,000 deg. C., and casting into a red-hot loam mould at 950 deg. C., did not show any appreciable increase in grain size.

Stability of $BaCl_3$ Modified Alloys.

It therefore becomes apparent that these alloys can be ingotted at their place of manufacture, sold and shipped and remelted without fear of reversion. It may be safely said that the BCl_3 method is the only one which will give any control over grain size. It has often been said that low casting temperature will give control in normal alloys, but not to anything like the extent that can be obtained with a boron-treated alloy. No control at all is possible in the case of normal solid solution alloys like zinc-aluminium alloys and pure metals, except by treating with BCl_3.

Now, as to the difference in alloys treated with boron trichloride, in the case of the silicon-aluminium alloys (Fig. 11) shows that the sodium modified metal appears under the microscope as a matrix of modified eutectic amongst which are the primary aluminium crystals. These crystals are in the proper dendritic form, appearing as long central needles with side branches at various angles to them. These large dendrites are the indication of a large grain size. When the same alloy is treated with the BCl_3 process the greatest effect made is that of breaking up these dendrites into nodules (Fig. 12). This indicates that the grain size has definitely been altered and made much smaller. The advantage of this will be dealt with later. At the same time, it will be seen that the silicon-alumium eutectic is extremely well modified, and its dispersion throughout the section is particularly good. No such fault as colonisation occurs, as is possible with the sodium method when too much sodium is used.

Unlike the sodium method of modification, boron can cause modification in a number of alloys other than the binary silicon-aluminium alloys. Fig. 13 shows the well-modified and even-grain size of a semi-solid solution alloy, *i.e.*, a 2 per cent. Si 13 per cent. zinc alloy. It is a composite picture of two examples of E11 B. The top half is a section of a ½-in. sand-cast bar and the bottom shows a section of a 2-in. chill-cast bar. This and the other alloys were all cast at the same temperature. The copper alloys are also considerably improved by this treatment. The normal alloys are notably very brittle in the sand-cast state: after treatment there is a great increase in their resistance to impact.

Grain Size and Mechanical Properties.

It is now best to consider the enormous importance of using metals where the size of the individual grain is very small. In aluminium-alloy castings this grain size is of vital importance in defining the strength, yield point, ductility and resistance to fracture under conditions of stress, alternating stress, impact, expansion or contraction and corrosion. Metal which tends to throw a large grain size on cooling is much more prone to hot-shortness. This defect can be developed by casting a double-ended T in a dry or green-sand mould. When the same composition of alloy is cast at the same temperature into two moulds of this shape, but having in the one case a fine grain throwing capacity and in the other a coarse grain-throwing capacity, it will be found that the coarse-grained casting is fractured, while the fine-grained casting is not. This effect can be brought about by treating one of the melts with chlorine and the other with boron chloride.

Such defects as surface fissures, shrinkage cracks, take place in a coarse-grained casting. These defects can be developed by casting a flat L-shaped plate about ¼ in. thick in green sand. By suitably altering the inflow of metal, using two runners, one with boronised metal and one untreated, it is possible to make the coarse grain appear in one part of the casting. In practically all cases the surface crack or fissure will follow the coarse-grain boundary. In some examples the crack can be seen by the naked eye. In the majority of cases the crack is not visible and only develops some time after the casting has been in service. When under the combined influence of corrosion and fatigue, a casting will fail by fracture along the coarse-grain boundaries. Should the crack in its path encounter an area of fine grain it will change its direction and continue through the adjacent coarse-grained area.

Conservation of Strength after Boronisation.

Much research work has been done in ascertaining the differences between these two types using the same composition of alloy. In tensile tests, which have been taken after subjecting them to a corrosion test, it has been found that bars having a coarse grain lose a very much greater proportion of their strength in comparison with the boronised alloy.

Over nine years' research work has been carried out with the object of finding aluminium alloys that would inherently resist corrosion and yet have valuable physical properties. During this period it was noticed time after time that failure of the metal after corrosion tests was primarily due to extensive intercrystalline corrosion. It is not possible to go into the large amount of work that has been done by Mr. D. R. Tullis on this subject except to say that when alloys were of coarse grain the intercrystalline corrosion failures were much more pronounced and in some examples the loss of ductility was so great that the metal could be broken with the hands. The trouble in this type of corrosion is entirely due to the grain boundary material. A metal which is a mass of grains between which are interposed the impurities (carbide, oxide, etc.) cannot be as ductile as a mass which is practically homogeneous. The effect of the corrosion is to release the hold the grains have upon each other, and the metal, as a whole, becomes more brittle. When the metal has a coarse grain this effect is much more pronounced. A fine-grained metal has a much larger boundary area; the impurities, therefore, become very much more dispersed throughout the metal. Boron-refined metals are thus more permanent in their resistance to corrosion. Where the impurities are localised, due to segregation, "pitting" of the surface will always develop.

Zinc Alloys.

Innumerable tests have been carried out as to the relative resistance to corrosion possessed by many alloys. It was concluded from these tests that alloys containing copper in quantities of over 2 per cent. are quite out of the question for resisting corrosion, probably due to electro-chemical action. Alloys containing 2 per cent. of copper and under possess inferior mechanical properties. Copper-zinc alloys are extremely liable to corrode. Nickel aluminium and silicon

FIG. 13.—ZINC ALLOY—TOP SAND—BOTTOM HALF CHILL CAST, BORON MODIFIED. × 50 DIA.

aluminium do not corrode rapidly, but develop local pitting. The most resistant alloys were found to be those containing pure zinc as the only alloying element. Until the introduction of chlorine and boron-trichloride treatment, the zinc alloys were generally condemned, due to the casting difficulties which are associated with impurity. The zinc alloys are very sensitive to the influences of the usual impurities and suffered much from the general belief that the zinc was the primary factor in the troubles that are almost always due to the presence of these impurities causing unsoundness. In properly treated zinc alloys, *i.e.*, by the foregoing methods, such troubles as hot-shortness and porosity due to the lack of proper fluidity, disappear. Tensile tests made on test-pieces of alloy E11 A, a plain zinc aluminium alloy, at a high temperature, 400 deg. C., gave 1.75 tons per sq. in. This serves to show that there is no hot-shortness. If the casting is bad when made with these alloys then the faults can be easily seen, as they are almost always external. This prevents time being wasted in waiting for the machining to discover the internal faults such as that known as "speckly" metal."

Summary.

Summarising, it would be as well to point out that, by using the treatments outlined, alloys have been developed that are really almost foolproof in casting and also one in particular that may be referred to as stainless, perhaps a new advent in aluminium metallurgy.

(*Continued on page* 108.)

Mass and Skin Effects in Cast Iron.

By H. W. Swift, D.Sc., Bradford Technical College.

(*Continued from page* 80.)

The Skin Effect.

In order to investigate the skin-effect directly, a number of tensile and compressive tests were carried out upon the bars after their diameters had been reduced by turning. Tensile tests were made on bars reduced by various amounts up to ½ in. on their diameter. Except in a few cases, included in Fig. 4, the material available did not permit systematic testing to be carried further. For the crushing tests, on the other hand, shorter lengths could be employed, and pieces down to ½ in. dia. were obtained and tested from each size of bar. The results of the tensile tests are shown in Fig. 4, those of the crushing tests in Fig. 5.

It will be seen that, following the tests on the rough bars, the tensile results are not so consistent as those of the crushing tests. This is due no doubt to the effect of small flaws in the metal which give rise to high local tensile stresses and accelerate failure in the one case, whereas they have little effect upon the ultimate

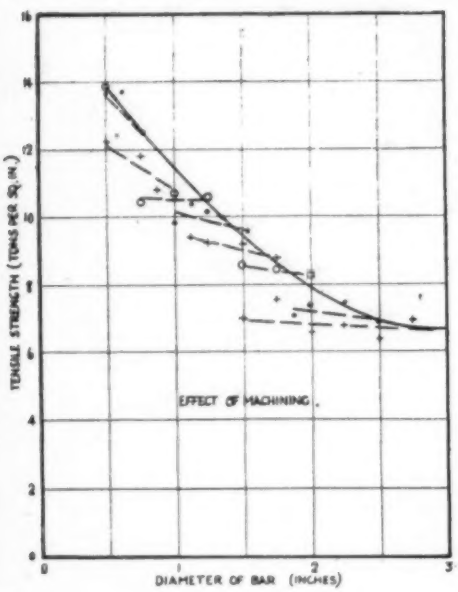

FIG. 4.

failure in compression. An absurdly exaggerated illustration of this effect would be the case of a saw-cut completely across the section of the bar; this would, of course, completely destroy its tensile strength, but might leave its compressive strength unimpaired. The same effect may help to explain the general tendency, also demonstrated by the tests, for the tensile strength of the bar to become increased by machining away the skin. Such flaws as do occur are more likely to be found near the skin, since the centre of the bar will be less close to the source of foreign material and gases and more completely in the flow of the clean metal. Consistent, also, with this explanation is the general tendency of the smaller bars to show the greater inconsistencies and also the greater increase in apparent strength on removal of the skin. If this view is correct, a weak spot is more likely to occur in the rough bar than in one which has had the skin removed, and since the tensile test is often more a test of weak spots than of real intrinsic strength, the core metal is made to appear slightly stronger than the skin. In any event, it seems safe to conclude from these tests that so far as the tensile test is concerned there is no evidence to show that the removal of the skin weakens the bar. This confirms the opinion expressed by Unwin and justifies his recommendation that cast bars should be turned before testing in order that accurate measurements can be made.

Since the completion of these tests results have been published by J. G. Pearce (International Foundrymen's Congress, 1929) showing a curious inconsistency. Transverse tests on one series of bars of similar composition gave evidence of an increase in strength due to machining, while tensile tests on another series showed a notable and continuous diminution as more and more metal was removed. Sufficient material remained from the present author's tests to check this result so far as tensile strength is concerned in the case of a bar 1½ in. diameter, and Table III shows no evidence of any considerable or progressive weakness towards the centre of the bars. As already mentioned, there is difficulty, in testing cast iron, to ensure truly axial loading. It is perhaps significant that errors in this particular lead to low results and also become most evident with smaller bars. They are, however, practically eliminated by Robertson grips such as were used in the present tests.

TABLE III.

Cast diameter, 1½ in.

Dia. of test-bar, In.	No. of tests.	Mean strength. Tons/sq. in.
1½	3	9.6
1⅜	1	10.0
1¼	3	10.2
1⅛	1	10.4
1	5	10.2
¾	3	10.4
½	3	9.9

Crushing Test shows Intrinsic Value of C.I.

The results of the series of crushing tests are shown in Fig. 5. As already indicated, these are generally more consistent and systematic than the tensile tests, and instead of an improvement they show a definite weakening of the bar when its skin is removed. This weakening is progressive up to a certain point as more and more metal is turned away, and then loses its effect. From these results it is reasonable to conclude that the compressive strength of cast iron does reside more especially in and near the skin, and that the skin-effect is felt, to a diminishing extent, of course, to a depth of, roughly, ⅜ in. below the surface. By suggesting that the skin-effect ceases at this depth it is in no sense implied that the metal beyond this depth is the same in all bars. The sytematic differences between the bars, which are seen from the results to be very marked at all depths, are then to be attributed to the "mass" effect in contradistinction to the "skin" effect.

The Metallurgical Aspect.

To gain a proper conception of the underlying significance of the "mass" and "skin" effects it is necessary to consider them in the light of metallurgical evidence. As regards the mass effect, the explanation is not difficult. Microscopic examination shows, of course, that the iron consists of pearlite, silico-ferrite and the phosphide eutectic, interspersed with free carbon. It also shows clearly that the tensile weakness of the iron is due to the free carbon; on examining the fracture of an already polished specimen it will be found that the line of failure is one following a path of least resistance and linking up the graphite particles, and all such particles near the line of fracture show distinct signs of opening out. Comparative examination of unetched specimens of the various sizes of bar shows that in the larger bars the graphite occurs in larger segregations and in lamellar as opposed to nodular form, and etched specimens show that the crystal size increases very much with the diameter of the bar and that the phosphide eutectic, while it constitutes a complete network in the smaller bars which have cooled comparatively quickly, appears more in the form of isolated inclusions in the larger bars. Chemical analysis showed that there was no appreciable difference in the actual amount of free carbon as between the various bars. This evidence points to the conclusion that, so far as ordinary grey iron of the class under test is concerned, the greater strength of the smaller bars as compared with the larger ones is due primarily to the shape and distribution rather than to the amount of the free carbon present. The regularity and completeness of the phosphide eutectic network no doubt has some influence on the hardness and abrasion figures, but it is unlikely that any differences in the intrinsic strength of the crystalline mass would become apparent in the presence of such a weak "link" as laminar graphite. Pearlitic, malleable, centrifugal, and alloy cast irons all seem to depend finally for their advan-

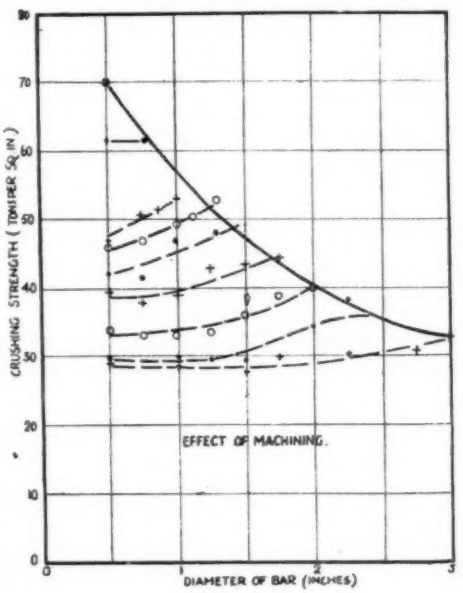

FIG. 5.

tages upon an innocuous form and distribution of their free carbon content.

When one turns to the skin-effect the explanation is not quite so obvious. On the mechanical side it is necessary to account for the following facts. As the skin is removed a continual diminution occurs in the crushing strength so long as the skin effect is present, and the hardness also becomes less. On the other hand, the tensile strength improves at first and then falls slightly after further turning, and there is the well-known skin "hardness" to machining. Microscopic comparison shows a gradual structural and crystalline change from the centre towards the edge of a bar, the tendency being towards smaller crystals and a closer and more reticulate structure near the skin. Both micro-examination and chemical analysis show that there are no signs of degraphitisation at any measurable depth below the surface, but the microscope shows that at the actual skin degraphitisation does occur. In the case of the larger bars a good deal of ferrite—in the form of silico-ferrite, no doubt—is to be found at the surface, while the pearlitic constituent is still present in the smaller bars. There was definitely

(*Continued on page* 108.)

Alloys Now Cast in Great Britain.

By Thomas Henry Turner, M.Sc.

(*Continued from page* 82.)

Cast Resistant Alloys.

The many modern alloys cast in Great Britain which possess remarkable resistance to corrosion, electricity or heat, form a fascinating study. They are difficult to review because of their complexity, lack of standardisation, proprietary character, and, in some cases, experimental nature.

In the main, they are dependent upon nickel for their resistant properties. Copper and chromium are often present in appreciable percentages, and tungsten, manganese, silicon and aluminium are often regarded as desirable additions in smaller quantities.

Alloys now cast for their especially good *resistance to corrosion* by the atmosphere, natural waters or chemicals, are:—(*a*) Cast nickel silvers; (*b*) cast copper-nickel alloys; (*c*) malleable cast nickel; (*d*) cast austenitic nickel-chromium steels, and (*e*) special cast irons.

Nickel Silvers.

The casting of the *nickel silvers* has been a steady business in the foundry for many years past, as these alloys are used in the form of harness equipment, buckles, motor-car fittings, and many such parts where a material superior to brass is required. In ordinary practice the copper content is about 60 per cent., nickel between 7 and 20 per cent., and the remainder zinc, but great variety of composition exists within these limits.

In the trade the following names and compositions are generally accepted; but, so far as one is aware, the first two grades are only used in the rolled or drawn conditions. The five subsequent grades are, however, typical of cast nickel silvers.

Table XXVI.—*Nickel Silvers.*

Names accepted in the trade.	Cu. Per cent.	Zn. Per cent.	Ni. Per cent.
B.B.	53	17	30
A.1	55	20	25
Best..	64	16	20
Seconds	60	25	15
Thirds	60	28	12
Fourths	60	30	10
Fifths	57	36	7

Copper Nickel.

For catering equipment and ornamental articles, copper-nickel alloys have become increasingly popular, the best known example of these being the 55 per cent. copper and 45 per cent. nickel alloy called "Silveroid," which has been cast with great success for all the ornamental metal work and window fittings of Imperial Chemical House, the finest of London's modern office buildings. It is only fair to add, however, that this alloy is much more widely used in the rolled or drawn conditions.

Though not a pure copper-nickel alloy, Monel metal may conveniently be mentioned here, as it is also being cast by many foundries throughout the country. It is required in an Admiralty specification to have a minimum U.T.S. of 20 tons per sq. in., and at least 12 per cent. elongation, but very much better figures are regularly obtained in practice. Typical test figures for cast Monel metal are now:—U.T.S., 25 to 30 tons per sq. in.; 25 per cent. elongation on 2 in, and Brinell hardness 110 to 140.

The high melting-point of nickel and Monel metal has entailed the mastering of a new foundry technique, but these alloys may now be seen cast in daily practice from a pouring temperature of between 1,500 and 1,650 deg. C. Up to 2 oz. of magnesium per 100 lbs. of Monel metal, or nickel, is added before pouring, to deoxidise and desulphurise the melt. As Monel metal shrinks ¼-in. per foot, a good head is necessary to ensure sound castings, and the metal being extremely brittle immediately following solidification, collapsible cores are essential to allow the casting to contract. The writer has only seen these alloys melted, for foundry purposes, in coke-fired crucible holes, but electric and oil-fired furnaces are also in use.

A new alloy with somewhat similar properties has recently been cast in a Midlands foundry, although of American origin. This alloy, "Everbrite 82," has a lower nickel-content and lower melting-point than Monel, and is said to be easier to handle in the foundry on that account. Its mechanical properties are excellent at elevated temperatures. They are:—Sp. Gr., 8.84; shrinkage, ¼-in. per foot; thermal conductivity, 0.060 calories per sq. cm. per deg. C. Others will be found in Table XXVII.

Table XXVII.—*Cast Corrosion-Resistant Alloys.*

Cast Corrosion-Resistant Alloys

Name.	Usual composition.	Brinell hardness.	Izod. Ft.-lbs.	U.T.S. Tons/sq. in.	E. Per cent. on 2 in.
Nickel-silver	Varies (*see* Table XXVI) ..	75–80	27	20–25	35–40
"Silveroid" ..	Per cent. Cu .. .. .. 55.0 Ni .. .. .. 45.0 Mn .. .. up to 1.0	90–100	44	25–27	45–50
Monel	Per cent. Ni .. .. .. 67.0 Cu .. .. .. 28.0 Fe .. .. .. 2.75 Mn .. .. .. 1.8 Si .. .. .. 0.3 C.C. .. .. .. 0.15 Gr. .. .. .. nil	120–140	107–115	20–30	12–25
"Everbrite 82"	Per cent. Cu .. .. 60.0–64.0 Ni .. .. 29.0–31.0 Fe .. .. 6.0– 8.0 Si .. .. 0.3– 0.5 Mn 0.25	170–200	—	33.5	14
Malleable cast nickel	Per cent. Ni .. .. .. 99.0 Mn, Mg, Si, C traces	80–90	46	28–30	50–55
"M.1 stainless steel"	Per cent. C .. .. 0.14–0.16 Mn .. .. 0.28–0.31 Si .. .. 0.04–0.24 Cr .. .. 17.8–18.0 Ni .. .. 8.0 –8.3	175	—	48	50

Malleable Cast Nickel.

Malleable cast nickel castings are in regular demand for chemical plant and food machinery, and, of the above alloys, nickel silver, "Silveroid" and malleable cast nickel are remarkably rough in the form of castings. Izod impact test figures averaged as follows:—Nickel silver, 27; Silveroid, 44, and malleable cast nickel, 46, in some tests which the author recently made on alloys supplied in the cast form, and none of the specimens was snapped in two by the impact.

Austenitic Ni-Cr Steel.

The melting of the austenitic nickel-chromium steels follows along almost identical lines. The writer has visited in the Birmingham area three specialist foundries, in which he has seen these new alloys cast. In one of them, in which nearly a ton of such castings is made per day, Monel metal and the austenitic nickel-chromium steel are cast as required, from the same special-type coke-fired furnaces.

Cast Iron.

Ordinary *cast iron* is superior to mild steel in resistance to corrosion, and might almost be classed as a resistant material, but it is greatly improved by the addition of high percentages of silicon, and of nickel, copper and chromium. The former type is an unmachinable silicide; the latter a machinable fine-grain grey iron. Both of these types of corrosion-resistant cast irons are now cast in Great Britain.

Electrical Resistance Alloys.

Alloy Cast Irons. Evidence has been lacking of any use of the relatively low nickel (5.0 per cent.) cast-iron resistance grid, which the author has seen cast in U.S.A., but non-magnetic, austenitic cast-iron grids are used. As pointed out earlier in this paper, a cast iron containing 10 per cent. of nickel and 5 per cent. manganese is cast into electrical resistance grids of high specific resistance. This alloy cast iron compares with ordinary cast iron and brass, as is shown by Table XXVIII. It is much tougher than ordinary cast iron, though equally strong in tension and of the same Sp. Gr., 7.2.

Table XXVIII.—*Comparison of Alloy Cast Iron, Ordinary Cast Iron, and Brass.*

—	Maximum magnetic permeability.	Specific resistance Michroms/c.c.	Resistance temperature coefficient. 0° C.–100°C.
"Nomag" ..	1.03	140.0	0.00045
Ordinary cast iron	330.00	95.0	0.0019
Brass	1.00	7.5	0.00156

Nickel-Chrome Alloys.—Some furnaces are at present being designed for electrical heating, in which the resistors are of cast "Nichrome." This alloy of American origin is now sand-cast in Great Britain for many purposes, and will be considered in further detail under the subsequent heading of "Heat-resisting Alloys." It should be stated here, however, that at room temperatures its specific resistance is about 117 michroma/c.c., and and that it is used for furnace heating units on account of its high strength and resistance to scaling at furnace temperatures.

Heat Resisting Alloys.

Alloys now cast for use as heat-resisting materials, *i.e.*, to resist oxidation and to carry stresses at elevated temperatures, are: (*a*) Nickel-chromium alloys; (*b*) nickel-chromium austenitic steels, and (*c*) special alloy cast irons.

Ni-Cr Castings.—The use of nickel-chromium castings has steadily increased, but they do not monopolise the heat-resisting alloy field. Where price is secondary to service the nickel-chromium alloys still excel. Where first cost must be as low as possible, and service is less regarded, other alloys compete. This is particularly the case where known liability to sulphide corrosion exists.

The following particulars (Table XXIX) have been received from foundries casting heat-resisting articles in alloys rich in nickel and chromium.

Table XXIX.—*Nickel-Chromium Alloy Castings.*

Proprietary name of alloy.	Composition. Per cent.	Brinell hardness.	U.T.S. Tons/sq. in.	E. Per cent. on 2 in.
"Cronite"	Ni 67, Cr 16, Fe 12 (Balance not specified)	235	32	2
"Nichrome"	Ni 60–65, Cr 15–18, Si 1.4–1.8, C 0.6–0.8 (Balance Fe, with small impurities)	160 to 200	29	3½

"Cronite" is being cast into annealing pans, cyanide pots, fire-bars, burner nozzles, pyrometer tubes, carburising boxes, and articles used for similar heat-resisting purposes. Its melting point is 1,420 deg. C. and Sp. Gr. 8.14. Though ten times, or more, as dear as the usual steels, its uses have steadily increased owing to its resistance to scaling. Its service life has frequently been 25 to 50 times greater than that of steel. Test pieces cut from a "Nichrome" casting, made in the course of usual work in the electric furnace, and pulled at temperatures increasing up to 1,100 deg. C., showed little alteration in the mechanical properties until 700 deg. C. Above that temperature the tensile strength falls off more rapidly to 2.7 tons per sq. in. at 1,100 deg. C., the elongation at that temperature being 20 per cent. on 2 in.

So far as the writer is aware, there are no standard specifications for any of these resistant alloys, unless one regards silver solders as coming under this category, they being the most resistant of the solders and frequently used in electrical work, and of which there are two grades, A and B.

A contains Ag 60 to 62; Cu, 27.5 to 29.5, and Zn, 9 to 11. B, according to B.E.S.A. Specification No. 206 of 1926, is to contain Ag 42 to 44; Cu, 36 to 38, and Zn, 18.5 to 20.5 per cent. In both the A and B grades the maximum impurities are not to be more than 0.5 per cent.

APPENDIX I.

The British Engineering Standards Association Specifications now in Force for Castings.

(Copies of these Specifications may be obtained from the offices of the B.E.S.A., 28, Victoria Street, London, S.W., by non-members of that Association, at a low cost, which is usually 2s. 2d. (post free) per Specification.)

Spec. No.	Year of issue.	Title.
		1.—Cast Iron.
40	1908	Cast-iron spigot and socket low-pressure pipes.
41	1908	Cast-iron spigot and socket flue or smoke pipes.
44	1909	Cast-iron pipes for hydraulic power.
58	1912	Cast-iron spigot and socket soil pipes.
59	1912	Cast-iron spigot and socket waste and ventilating pipes for other than soil purposes.
78	1917	Cast-iron pipes and special castings for water, gas and sewage.
K.11	1919	Iron castings for pistons and water-cooled cylinders.
K.12	1919	Iron castings for valve guides and air-cooled cylinders.
154	1922	B.S. dimensions for malleable and soft cast-iron pipe fittings for steam, water and gas.
5017	1923	B.S. dimensions for: (1) cast-iron couplings for propeller-shafts; (2) bore, length and keyway of propeller bosses for small motor-driven vessels.
5024	1924	Iron castings for air-cooled and jacketed cylinders for automobiles.
5025	1924	Iron castings for sand-cast pistons and valve guides for automobiles.
5026	1924	Iron castings for flywheels for automobiles.
189	1925	Cast-iron fitter plates and frames.
309	1927	White-heart malleable-iron castings.
310	1927	Black-heart malleable-iron castings.
5004	1927	Cast-iron piston-ring pots, sand and chill-cast, for automobiles.
321	1928	General grey-iron castings, grades A and C.
4 K.6	1928	Cast-iron piston-ring pots (sand-cast and chill-cast).
		2.—Cast Steels.
30	1907	Steel castings for marine purposes.
24 (Part 4)	1921	Railway rolling-stock material; steel forgings, blooms and castings.
150	1922	Cast-steel wheel centres for electric tramway cars.
153	1922	Girder bridges materials and workmanship.
5028	1924	Steel castings (Nos. 1 and 2 grade) for automobiles.
		3.—Cast Yellow Metals.
B.2	1917	Gunmetal castings.
B.8	1917	Phosphor-bronze castings for bearings.
B.14	1918	Common brass castings.
208	1924	Special brass castings.
263	1926	Brazing solders.
		4.—Cast White Metals.
219	1925	Soft solders.
334	1928	Chemical lead.
335	1928	Regulus metal.
		5.—Cast Light Alloys.
2 L.5	1921	Aluminium-alloy castings suitable for crank-cases and general use.
2 L.8	1921	12 per cent. copper aluminium-alloy castings.
3 L.11	1921	7/1 aluminium-alloy castings.
L.24	1921	Y aluminium-alloy castings.
361	1929	7 per cent. copper aluminium-alloy castings for general engineering purposes.
362	1929	12 per cent. copper aluminium-alloy castings for general engineering purposes.
363	1929	Zinc-copper aluminium-alloy castings (suitable for crank-cases and general use).

APPENDIX II.

Standardisation of the raw materials used by foundrymen in making up their alloys has not proceeded very far yet in Great Britain, but the following B.E.S.A. Specifications are now in force, and are recorded here for the sake of completeness.

Spec. No.	Year of issue.	Title.
		Copper.
199	1924	Electrolytic copper ingots and ingot bars.
202	1924	Electrolytic cathode copper.
203	1924	"Best select" copper.
198	1925	Electrolytic copper wire bars, cakes, slabs, and billets.
		Brass.
207	1924	Special brass ingots for castings.
		Zinc.
220	1926	Fine zinc (or spelter), grades A and B.
221	1926	Special zinc (or spelter).
222	1926	Foundry zinc (or spelter).
		Aluminium.
359	1929	98 per cent. aluminium: (1) notched bars and ingots for remelting purposes.
360	1929	99 per cent. aluminium: notched bars and ingots.

Some Developments in Aluminium Metallurgy.

(Continued from page 105.)

Quick melting, in crucibles that are free from carbon, carborundum crucibles are recommended, goes a long way to prevent the melt from being gassed and undue formation of oxide. This is, by the way, difficult to remove; it does not all float as dross. Careful control of temperature is all-important for repetition work. Since the metal tends to absorb gas, the lower the temperature at which pouring is done, the less volume of gas likely to be frozen into the casting when it sets, because the gas leaves the metal as it cools. Also, total shrinkage is a function of the pouring temperature. If a casting were poured at 900 deg. C. it would have to shrink some 3½ per cent. before it reached 650 deg. C. Together with the natural contraction, this means feeding of an order which is seldom possible in practice, and one would get a casting cracked and drawn, with an open-grained and porous structure. It is this tendency to pour thin castings with hot metal that renders difficult the production of good castings. BCl-treated alloys show little trouble in this respect, and, indeed, their strength in thin sections is one of their outstanding characteristics. In conclusion, it is desired to point out that the writer is indebted to Mr. D. R. Tullis for the facts used as the basis of this Paper.

Mass and Skin Effects in Cast Iron.

(Continued from page 105.)

no indication of any tendency for cementite to appear at the surface of even the smallest of the bars under consideration, and the only observable factor which might possibly influence the machinability of the iron was foreign matter—presumably sand—embedded in and near surface irregularities. From these observed facts it would appear that the skin effect is two-fold. There is a continual tendency for the metal to improve in mechanical properties from the centre outwards owing to more rapid cooling and consequent improvement of structure. On the other hand the skin itself is at once weakened and made more difficult to machine, not by any chilling tendency, but by surface inclusions of sand from the mould.

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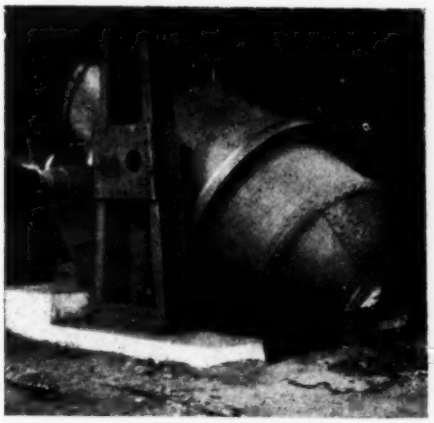

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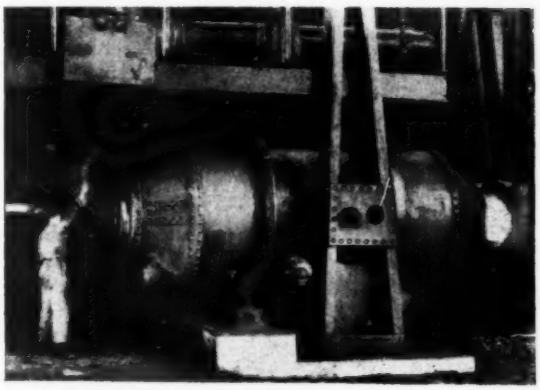

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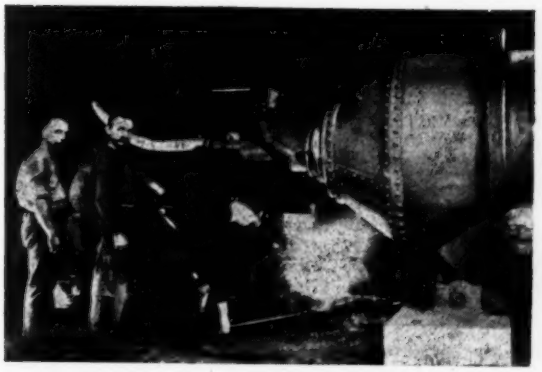

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American Production of Centrifugal Cast-Iron Pipe.*

The production of centrifugal pipe in America last year occupied an increasingly important position in the total cast-iron pipe output. It is estimated to have contributed 500,000 tons to the total, compared with an estimate of 425,000 tons in 1928, 400,000 tons in 1927 and only about 200,000 tons in 1926. The production of both pit-cast and centrifugal pipe is estimated at slightly less than the 1,315,198 tons in 1928, which was smaller than the 1,437,698 tons of 1927, and a further slight decline from the peak year of 1926, when production reached 1,534,278 tons.

The year has been one of the poorest business years experienced by the American pipe industry since the war period. Although the mileage of pipe laid was undoubtedly greater than indicated by the tonnage of sales, there was an unusually heavy demand last year for large sizes of pipe, ranging from 20 in. to 48 in. Throughout 1929 inquiries including a substantial tonnage of large-diameter pipe were frequent.

Distribution of Exports.

The export of pipe from America was generally limited to small lots, but widely distributed; shipments were consigned to consumers in Mexico, Cuba, Hayti, Porto Rico, Dutch West Indies, Brazil, Argentina, Chile, Russia, Japan and all the Central American countries except Guatemala. The heaviest export buying was by the Philippines, which placed orders for about 15,000 tons of pipe, ranging from 4 in. to 42 in. The importation of pipe was even lower than in 1928, when the total for the year declined to about 65,000 tons from 81,764 tons in 1927.

New Plant for Construction.

The Warren Foundry & Pipe Company, Phillipsburg, N.J., and the leading shipper of foreign cast-iron pipe to the United States, were the only companies to project new construction, and they made but little progress with their plans. The Société Anonyme des Hauts Fourneaux et Fonderies de Pont-a-Mousson, of Pont-a-Mousson, France, decided to establish an American plant, undoubtedly influenced by the proposed increase in the duty on cast-iron pipe recommended in the Smoot-Hawley tariff. Property was acquired at Chelsea, Mass., and construction was commenced on a dock and a railway siding. A foundry with 150,000 tons annual capacity is planned for construction this year.

About the same time, the Warren Foundry & Pipe Company, which had been considering the establishment of a sand-spun centrifugal-pipe plant in the New England district, acquired property at Everett, Mass., adjoining the Mystic blast furnace, filled the low ground, and at the end of the year contracted with the McClintic-Marshall Company for a foundry with an annual capacity of about 35,000 tons.

Manufacturing Licences Granted.

The world capacity for centrifugal-pipe production experienced further increases. The Sand Spun Pipe Corporation licensed two British foundries and the leading French producer of cast-iron pipe to operate under its patents. In Canada, a Hamilton pipe foundry, licensed in the autumn of 1928, started its full production of sand-spun pipe.

A development during 1929 in pipe production was the manufacture of 18-ft. lengths of centrifugal pipe by the leading concern, progressing another step from the 12-ft. sections made up to about 1914. Experiments were conducted by a manufacturer of centrifugal pipe, operating under the sand-spun patents, in an effort to cast large diameters centrifugally up to 48 in.

* Extracted from an article in the "Iron Age."

Features of the Cleveland A.F.A. Convention.

Greater interest shown by an increasing attendance at the round-table meetings and shop-operation courses, which formed a part of the past few conventions of the American Foundrymen's Association, has led the Programme Committee to broaden the scope of these sessions for the 1930 annual meeting. The programme for this year's convention, scheduled for the week of May 12 at Cleveland, provides for three round-table luncheon meetings, covering malleable, steel and non-ferrous foundry practice.

The chairmen selected to lead these meetings are well-known leaders in their respective branches of the industry. Mr. H. M. St. John, metallurgist for the Detroit Lubricator Company, Detroit, will preside at the non-ferrous meeting; Mr. W. J. Corbett, Fort Pitt Steel Castings Company, McKeesport, Pa., will lead the steel group; and Mr. P. C. DeBruyne, Moline Malleable Iron Company, St. Charles, Ill., will act as chairman for the malleable group. No specially-prepared Papers will be presented at these informal luncheon meetings, but every one present will be given an opportunity to propose and to discuss any phase of management, metallurgical or shop practice he cares to introduce.

Three shop-operation courses, organised expressly for the practical shopman, are scheduled. These will cover steel foundry operation, grey-iron foundry operation and non-ferrous foundry practice. Each course will consist of a series of three or four sessions, the leaders for each session being assigned a definite subject for discussion. Thus, Mr. W. F. Graham, of the technical division, Ohio Brass Company, Mansfield, Ohio, is in charge of organising the course for the non-ferrous foundrymen. The subjects which will be discussed at this course include crucible, open-fire and electric furnace practice.

Mr. D. E. Broggi, foundry superintendent and metallurgist, Neptune Meter Company, Long Island City, N.Y., will lead the discussion on the indirect-arc-type furnace, and Mr. C. H. Morken, plant metallurgist, Ohio Brass Company, Mansfield, Ohio, will open a talk on the induction-type furnace.

The steel-foundry course is being organised by a committee consisting of Mr. John Howe Hall, Taylor-Wharton Iron & Steel Company, High Bridge, N.J.; Mr. F. J. Stanley, works manager Michigan Steel Castings Company, Detroit; and Mr. C. D. Carey, works manager, American Steel Foundries, Verona, Pa. Sessions outlined for the steel course will cover chipping, grinding and riser removal, heat-treating and heat-treating equipment, and core practice—including anchoring, rodding, venting and sand mixtures.

Four sessions will comprise the grey-iron shop-operation course. The first sessions will cover cupola materials, and will be under the direction of Mr. C. J. Scullin, Tucker-Scullin Inc., St. Louis. Mr. Scullin will be assisted by Mr. E. J. Lowry, consulting metallurgist, of Detroit.

Cupola materials and operation will be discussed at the second session, under the leadership of Mr. R. S. MacPherran, chief chemist, Allis Chalmers Manufacturing Company, Milwaukee. He will be assisted by Mr. F. J. Walls, metallurgist, Wilson Foundry & Machine Company, Pontiac, Mich., and by Mr. James T. MacKenzie, metallurgist, American Cast Iron Pipe Company, Birmingham, Ala. The third session will be devoted to a discussion of gating and risering, and will be led by Mr. H. W. Dietert, foundry engineer, U.S. Radiator Corporation, Detroit.

Those attending the fourth session will deal with high-duty irons, alloy additions and heat-treatment of cast iron. Leading this session will be Mr. H. Bornstein, metallurgist, Deere & Company, Moline, Ill., who will be assisted by Mr. F. B. Coyle, research metallurgist, International Nickel Company, New York. In addition to these round-table meetings and shop-operation course sessions, the usual sessions covering technical and managerial phases of the foundry industry will be held.

Rust Spots on Iron Castings.

By Neville Deane.

A very peculiar trouble which once occurred in an iron foundry specialising in tinned and enamelled hollow-ware was a veritable plague of rust spots on the castings. These spots were distributed over the castings both inside and outside and developed during the night following casting. More peculiar still was the fact that after sand-blasting in preparation for enamelling, if there was another night's delay prior to being enamelled, the rust spots again developed. It was, of course, quite impossible to enamel the castings in such a state, and a very slow and costly process of scraping was necessary to get the castings in suitable condition for the first coat of enamel.

Some of the castings for tinning, such as saucepans, were turned inside and did not present such difficulty, but others, such as mincers, were almost as much trouble to tin as the others were to enamel. The solution of the problem, when investigated, was really very simple, but a great deal of difficulty was experienced in obtaining the facts on which to base the investigation, which is often the case with foundry problems, and it is generally the obscure fact, not thought to be worth correlating, which is the most important.

However, as this case was really serious, much time and energy was expended in testing every conceivable factor. It was first surmised that the air was at fault (fumes from chemicals or other similar cause), but extensive tests showed nothing wrong there. One important fact, however, resulted, and that was that the castings only showed the rust spots when the air was moist. Castings in dry air did not rust, but in moist air, whether under cover or not, they invariably rusted in a short time.

Primarily, the iron was analysed and microscopically examined, the facing sand was similarly tested, coal dusts of various grades were analysed and tried, but all to no avail. Finally, the only factor remaining was the water used to damp down the sand. This idea was more or less ridiculed, as everyone was sure the water was quite good. However, it was decided to examine the water supply, and it was found that it was anything but pure.

Impure Water the Culprit.

As the water was apparently taken from quite a good well this was rather mysterious, but further investigations showed that there was a very active source of contamination. Considerable quantities of water, ammonium chloride, hydrochloric acid and other chemicals were used in the tinning shops. The waste from these shops was drained off into another well, where it was treated with lime to destroy the free acids. But, being now considered "good" water, it was allowed to drain into the well from which the foundry water was taken. Tests with this water, as might be expected, showed large quantities of calcium chloride.

Finally it was found that by the use of this impure water spots of fused chloride were made here and there in the skin of the castings. In a moist air the very deliquescent chloride absorbed water and rusted the iron. Sand-blasting did not remove the fused spots, and so rusting again occurred when the casting was exposed to the moist atmosphere.

By the use of really clean water to moisten the sand the rust spots were entirely banished, but whether the use of the clean water, at a higher cost than the impure well-water, was an economic proposition was, of course, a point for the management to decide, and outside the province of the laboratory.

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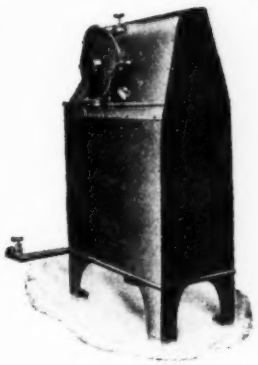

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Trade Talk.

Messrs. Sir James Laing & Sons, Limited, shipbuilders, of Sunderland, are shortly to start a marine engineering department.

Messrs. John Hall & Company, of Stourbridge, Limited, Fire Clay and Brick Works, Stourbridge, announce that their telephone number from February 8 will be Stourbridge 5055.

The Carron Company have issued a leaflet commemorating the birth of Robert Burns on January 25, 1759, and recording the circumstances of a visit paid to the Carron Works by the Scottish poet.

Contributions to charities in the West of Scotland have been made by the employees of the following firms :—Sir William Arrol, Limited, Dalmarnock and Parkhead Iron Works, £500; Smith & Wellstood, Limited, Bonnybridge, £361 15s.; and Glengarnock Iron Works, £953.

Intimation has been made to the Scottish Manufactured Iron Trade Conciliation and Arbitration Board that the average net selling price for November and December, 1929, was £10 11s. 5.2d. This means that there will be a reduction of 2½ per cent. on basis rates in the wages of the workmen.

Messrs. D. & W. Henderson & Company, Limited, Partick, have received a contract from Messrs. Worms & Company, Paris, to build two steamers of about 2,500 tons deadweight capacity and two others of 1,550 tons deadweight capacity, designed to have a speed of 10½ to 11 knots.

British Reverberatory Furnaces, Limited, proprietors of Sklenar patent furnaces, have removed from 82, Victoria Street, S.W., to 88, Kingsway, London, W.C.2. The telephone number is Holborn 3622, whilst the telegraphic address is "Furnaces," c/o Tramway, Phone, London.

An offer made to the receiver of Messrs. Clayton & Shuttleworth, Limited, Lincoln, by Messrs. Marshall, Sons & Company, Limited, to purchase the goodwill and business has been accepted. The Stamp End works of Messrs. Clayton & Shuttleworth, Limited, are not included in the transaction.

The Darwen & Mostyn Iron Company, Limited, have now two blast furnaces at Mostyn, as against three formerly. Two old furnaces have recently been dismantled and replaced by one modern unit. The firm state that the plant is now laid out efficiently to manufacture ferro-alloys on an economic basis.

The plans for the merger of the Republic Iron & Steel Company, the Central Alloy Steel Corporation, the Donner Steel Company, Incorporated, and the Bourne-Fuller Company, four of the largest steel manufacturers in the Middle West of the United States, have been approved by the shareholders. The new corporation is to be called the Republic Steel Corporation.

The Anglo-Persian Oil Company, Limited, have ordered from the Albion Motor Car Company, Limited, Scotstoun, a fleet of thirty 4-ton vehicles, mainly intended for use in this country. The Egyptian State Railways have placed orders for structural steel work for bridges with Messrs. P. & W. Maclellan, Limited, Glasgow, and Messrs. Redpath, Brown & Company, Limited, Edinburgh.

Messrs. Dorman, Long & Company, Limited, have decided to close down their Carlton Ironworks in March. There are three furnaces at the works, but only one, which is making ferro-manganese, is at present in operation. The production of ferro-manganese will be transferred to the South Bank Ironworks, which were recently taken over from Messrs. Bolckow, Vaughan & Company, Limited.

The Low Moor Iron Company, Limited, inform us that their furnace has been relighted, and is producing pure cold-blast pig-iron, made direct from the blast furnace, without the addition of any scrap and without any hot-blast whatsoever. Mr. T. L. Poole resigned his position recently as blast-furnace manager, and in his place the company has appointed Mr. H. Essex, who for 24 years has been with Messrs. G. & R. Thomas, Hatherton Furnaces, Bloxwich.

International Combustion, Limited, have received a contract for a complete boiler plant, comprising boilers, air-preheating equipment, pulverising plant and auxiliary machinery, for the B'wana M'Kuba Copper Mines, South Africa. Most of the equipment will be manufactured at the firm's Derby works. A contract for stoker-fired boiler plant for the Ryde Pumping Station of the Sydney Water Board, New South Wales, has also been placed with the company.

The directors of the English Steel Corporation, Limited, have informed the Penistone, Thurlstone and Hoylandswaine Urban District Councils that they cannot alter their decision to close the steelworks at Penistone. With regard to the future of the works, the hope has been expressed that they will be taken over by another company. The directors of the English Steel Corporation, Limited, have told the local authorities that they would put no obstacle in the way of the realisation of this suggestion.

The centrifugal casting of steel slabs was demonstrated recently at the Canton works of the Central Alloy Steel Corporation, Ohio, U.S.A. The machine, which was designed by Mr. Leon Cammen, of New York, has a revolving element 7 ft. in diameter. Radial separators around the periphery inside provide for making the curved slabs, which may then be rolled in more or less the usual manner. The invention is, of course, planned to displace the casting of ingots and the subsequent breaking down of the ingots in a blooming mill.

Messrs. Stein & Atkinson, Limited, 47, Victoria Street, London, S.W.1, have received an order from the Stanton Ironworks Company, Limited, for a continuous pipe-annealing furnace for the heat-treatment of their spun pipes. The furnace will be designed on similar lines to other furnaces which have been installed at Stanton by Messrs. Stein & Atkinson, Limited, but will be of a larger size to deal with pipes of up to 16-in. internal diameter and 18 ft. long. A further Chapman-Stein gas producer will also be supplied for firing this furnace.

During the past year the Dominion Iron & Steel Company, a subsidiary of the British Empire Steel Corporation, has passed through the most active period in its history, steel ingots produced totalling 407,000 tons and pig-iron 306,000 tons. Of the company's steel production, Canada absorbed roughly 88 per cent., and export business accounted for 12 per cent. In addition, 830,000 tons of iron ore were shipped from the company's Wabana mines in Newfoundland to Germany and the United States. The company uses about a quarter of the entire coal output of the Cape Breton mines, varying from 800,000 to 1,000,000 tons.

About 200 men are working under protest at Motherwell Iron Works owing to a reduction in wages in consequence of a change in the basis of payment. The matters in dispute are under consideration by officials of the trade union concerned and the management. There is a difference between the rates for working steel and the rate for iron. It would appear that it has been the custom in ironworks when a mill was on steel, which is easier handled than iron, to pay the workers iron rates, which are from 16½ to 17 per cent. higher than steel rates. The dispute resolves itself into a question of adjustment of rates between the parties. The matter is one that affects the trade generally, and is unlikely to be confined to Motherwell works.

Amongst the recent Clyde launches are the following :—The "Clan MacAlister," a steamer of 10,750 tons deadweight carrying capacity, built for the Clan Line Steamers, Limited, by the Greenock Dockyard Company, Limited; the "Genova," a twin-screw motor cargo vessel, built by Messrs. Harland & Wolff, Limited, to the order of the Argentine Navigation Company (Nicolas Mihanovich), Limited; the steamer "Emperor," built by the Ailsa Shipbuilding Company, Limited, for Messrs. J. Hay & Sons, Limited, Glasgow; and the screw steamer "Ramsay," built by Messrs. Robert Duncan & Company, Limited, Port Glasgow, for the Bolton Steam Shipping Company, Limited, London, the machinery being supplied by Messrs. David Rowan & Company, Limited, Glasgow.

Details have been published of the North-East England Electricity Scheme, which has been adopted by the Central Electricity Board. The scheme deals with over 5,000 square miles, covering the counties of Northumberland and Durham and part of the North Riding of Yorkshire. In view of the organised and intensive electrical development in the industrial parts of the area, of which the greater part has been carried out at a non-standard frequency of 40 cycles per second, the preparation of the scheme has involved economic and engineering considerations of an unusual character. It will be necessary, in order to link up the North-East Coast with the great national plan for the co-ordination of electricity supply throughout the country, to bring all the electrical machinery and apparatus in the area into line with the standard frequency of 50 cycles a second. The gross expenditure involved in standardisation is estimated to be at least £9,000,000, to be carried out on a five-year programme.

Personal.

Mr. J. L. Richardson, of Hull, is to succeed Mr. J. Denholm Young as President of the Society of Consulting Marine Engineers and Ship Surveyors.

Sir Ernest Rutherford, O.M., F.R.S., has been awarded the Faraday Medal of the Institution of Electrical Engineers. The Faraday Medal is awarded by the Council of the Institution, not more frequently than once a year, either for notable scientific or industrial achievement in electrical engineering or for conspicuous service rendered to the advancement of electrical science.

Mr. W. H. Hudson, transport manager of Messrs. Bolckow, Vaughan & Company, Limited, who has retired following the fusion with Messrs. Dorman, Long & Company, Limited, has been the recipient of a presentation from the transport managers of Messrs. Dorman, Long & Company, Limited, the Cargo Fleet Iron Company, Limited, Messrs. Pease & Partners, Limited, and Messrs. Sadler & Company, Limited.

Wills.

Dickson, David, Falkirk, late a director of the Forth & Clyde & Sunnyside Iron Companies, Limited £152,693

Bradshaw, G. (81), of Southport, governing director of George Bradshaw & Company, Limited, metal merchants, of Manchester £14,058

Obituary.

We regret to announce the death of Mr. G. P. Rawstron, aged 49, proprietor of Messrs. Westoby & Rawstron, and chairman of Messrs. Rawstron, Westgarth & Company, Limited, both houses being well known in the metal industries. Mr. Rawstron was a popular member of the Manchester Exchange, where he did business with many of our readers in the North Midlands. He was interred last Tuesday at Liverpool, and leaves a widow and two sons. He was also a member of the Iron and Steel Institute and the Junior Constitutional Club.

Contracts Open.

Belfast, February 10.—Iron and steel stores, for the L.M. and S.R. Northern Counties Committee (Ireland). Mr. F. J. Martin, stores superintendent, York Road Station, Belfast. (Fee 6d., non-returnable.)

Ely, February 7.—4,920 yds. of 6-in. cast-iron pipes, 2,328 yds. of 4-in. and 342 yds. of 3-in., etc., for the Ely Urban District Council. Mr. G. A. J. Edmundson, 45, Silver Street, Ely. (Fee £1 1s., returnable.)

Leeds, February 18.—Copper and iron castings, bolts, nuts and screws and weldless steel tubes, for the Electricity Department. Mr. C. Nelson Hefford, general manager, Electricity Department, 1, Whitehall Road, Leeds.

London, S.W., February 7.—Pig-iron, copper rods and tubing and steel material, for the Bombay, Baroda and Central India Railway Company. The White Mansion, 91, Petty France, Westminster, S.W.1. (Fee 10s., non-returnable.)

Wigtown, February 13.—2¼ miles of cast-iron pipes, etc., for the Town Council. Messrs. Crouch & Hogg, civil engineers, 17, Lynedoch Street, Glasgow. (Fee £1 1s., returnable.)

New Companies.

Willey & Company, Limited, Water Lane, Exeter.—Capital £1,000 in £1 shares. Engineers and manufacturers of gas or electrical apparatus, etc.

William Elliss & Sons, Limited, Lock Street Foundry, Sheffield.—Capital £8,000. Ironfounders, etc. Directors: J. A., F., W., and T. D. Elliss.

Reports and Dividends.

Dalmellington Iron Company, Limited.—Interim dividend of 2½ per cent.

J. & E. Hall, Limited.—Profit, £60,379; brought in, £7,396; final dividend of 5 per cent., making 8½ per cent. for year; carried forward, £9,675.

The mail steamer "Avon," belonging to the Royal Mail Steam Packet Company, has been sold to Messrs. Thos. W. Ward, Limited, and is to be dismantled.

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now offer to meet any foreign competition.

We offer to supply British Steel Foundry Sand

AS CHEAP AS ANY FOREIGN SAND OR CHEAPER
AS GOOD AS ANY FOREIGN SAND OR BETTER

AND we will give you instant delivery from one of four points.

☞ **In truck loads** (not asking for orders for 200 or 300 tons)

☞ **On Monthly Account**
(Not asking for cash against Bill of Lading)

WE KNOW YOU REALLY PREFER TO USE BRITISH SAND AND WE HERE AND NOW INVITE YOU TO ACCEPT OUR OFFER AND TO COMMUNICATE WITH US.

Iron and Steel Markets.

Pig-Iron.

MIDDLESBROUGH.—Current demand for pig-iron on Tees-side continues sluggish, without, as yet, any promise of an early improvement, such as had been confidently anticipated at the turn of the year, when optimism was the prevailing note in the Cleveland market. Buyers are still apparently content to pursue a purely hand-to-mouth policy, and forward buying has almost ceased. Moreover, two blast furnaces in the district, blown out before Christmas, have not been replaced, and it is now very uncertain when that step will become necessary. There are now 42 blast furnaces operating on the North-East Coast as against a maximum of 47 last year. The decline is not serious, but it indicates that industrial worries are not yet subdued. On the export side some improvement is denoted in the returns of shipments from Tees-side during the past month, the total tonnage having been considerably in excess of that recorded in December, while sales to Scotland also disclose a satisfactory increase in volume. A rather substantial reduction in prices of blast-furnace coke recently effected encourages the hope of a revision of pig-iron values, but ironmasters do not share that sanguine view of the position, contending that costs of production are still too heavy to allow any margin of profit to producers. Consequently prices are still firm at the following minimum rates:—No. 1 Cleveland foundry iron, 75s.; No. 3 G.M.B., 72s. 6d.; No. 4 foundry, 71s. 6d.; No. 4 forge iron, 71s. per ton.

The position in the East Coast hematite market during the current week has developed a weaker tendency, and new business is distinctly on the slack side. Thus the outlook is less hopeful and, there being no price agreements in the hematite trade, there is keen competition for any orders in circulation. Possibly makers might be disposed to take a firmer stand, but there is a fair amount of iron in merchants' hands, and the latter are freely offering mixed numbers at 78s. per ton, a figure which is said to be below cost. No. 1 is at a premium of 6d. per ton. On the North-West Coast prices are higher, Bessemer mixed numbers now being quoted at 79s. at works.

LANCASHIRE.—Last week's decision of the Midland ironmasters to leave quotations undisturbed has had little effect on the Lancashire markets for foundry pig-iron, buying on fresh account at the moment being on a very limited scale. So far as current consumption is concerned, Lancashire foundries on the whole are specifying for fair quantities, and there has been no noticeable falling-off in this respect. Current quotations still rule on the basis of 77s. per ton for Derbyshire and Staffordshire makes, with Scotch brands at 95s., delivered local stations.

THE MIDLANDS.—In the Birmingham area ironfounders, in certain classes of trade, find that there has been a falling-off in business, and they are not at all anxious to commit themselves in these circumstances for forward supplies. The market for foundry pig-iron is consequently inactive, with prices unchanged, quotations still ruling at 75s. for No. 3 Northants and 78s. 6d. for No. 3 North Staffordshire and No. 3 Derbyshire, delivered to local stations.

SCOTLAND.—The market for Scotch foundry pig-iron continues quiet, and business seems to be getting worse instead of improving. Ironfounders in general complain of lack of orders, and some of the largest and most favourably situated foundries are working short time. Prices remain firm on the basis of 78s. for No. 3 Scotch foundry f.o.t. furnaces, with a minimum of 2s. 6d. per ton extra for No. 1.

Finished Iron.

At Birmingham this material remains a disappointing market in so far as crown and the cheaper grades of manufactured iron are concerned. Prices for the former are from £10 to £10 10s. Good Staffordshire crown iron is quoted at £10 5s. Nut and bolt iron is offered at from £9 2s. 6d. to £9 7s. 6d., but little support is forthcoming from users because of the offers of foreign bars at a much lower price. There continues to be a fair demand for Staffordshire marked bars at £12 10s. at works and for cable and other tested irons.

Steel.

Sheffield manufacturers report heavier foreign competition in alloy and tool steels, but against this is a constantly increasing demand for stainless and special high-quality steels. Of the 80 open-hearth steel furnaces in this area, half are out of action at present. Other British works have received a fair share of the orders passing and lately have taken some business which usually goes to the Continent. Quotations at Sheffield now rule:—Siemens acid billets, £9 10s.; basic billets, soft, £6 15s.; medium hard, £7 12s. 6d.; medium, £8 2s. 6d.; hard, £9 2s. 6d. to £9 12s. 6d.; basic wire rods, soft, £8; medium hard, £9 15s. to £10; hard, £10 10s. to £11; acid, £12 5s. to £12 10s. In the tinplate market current quotations are 18s. 6d. to 18s. 9d. basis for coke tinplates, net cash, f.o.b. South Wales ports.

Scrap.

The volume of business now passing in markets for foundry scrap metals continues on a very moderate scale, and the demand for this material still leaves much to be desired. On Tees-side prices are unchanged, and 62s. 6d. is the recognised market figure for ordinary heavy cast iron, though 66s. 6d. per ton has been paid for machinery quality. In the Midlands, there is still a good demand for heavy cast-iron scrap at 70s. delivered, and for light metal at 60s. In Scotland, machinery cast-iron scrap is still quoted at 70s. for material suitable for foundries, with heavy ordinary cast iron at 65s., and light cast-iron scrap at 60s. The above prices are all per ton delivered f.o.t. consumers' works.

Metals.

Copper.—Despite adverse rumours regarding over-production and super-heavy stocks in the States, the market for warrant copper maintains its remarkable steadiness, although business on the whole remains quiet and uneventful. Consumers are evidently still restricting their buying as much as possible, and several big schemes are believed to have been held up in consequence.

Closing quotations are :—

Cash.—Thursday, £72 to £72 2s. 6d.; Friday, £71 17s. 6d. to £72 2s. 6d.; Monday, £72 7s. 6d. to £72 10s.; Tuesday, £72 15s. to £73; Wednesday, £72 17s. 6d. to £73.

Three Months. — Thursday, £68 15s. to £68 17s. 6d.; Friday, £68 12s. 6d. to £68 15s.; Monday, £69 to £69 2s. 6d.; Tuesday, £69 to £69 2s. 6d.; Wednesday, £69 5s. to £69 7s. 6d.

Tin.—The position in the market for standard tin continues uncertain, and greatly dependent upon the success of the various schemes for curtailment of output throughout the industry at the chief centres of world production. This has been estimated by a leading authority as no less than 10,000 tons, which must eventually have an effect on prices, the present heavy stocks meaning that an adjustment between supply and demand will be a slow process.

Official closing prices :—

Cash.—Thursday, £178 to £178 5s.; Friday, £176 12s. 6d. to £176 15s.; Monday, £174 15s. to £175; Tuesday, £176 15s. to £177; Wednesday, £176 17s. 6d. to £177.

Three Months.—Thursday, £181 2s. 6d. to £181 7s. 6d.; Friday, £179 12s. 6d. to £179 15s.; Monday, £177 17s. 6d. to £178; Tuesday, £179 15s. to £180; Wednesday, £179 17s. 6d. to £180.

Spelter.—Business in this section of the base metal markets presents a rather more encouraging aspect than recent reports have suggested, which may be explained by the magnitude of the accumulated stocks, now amounting to 120,000 tons, against a normal level of about 50,000 tons. The demand from consumers has improved, and, consequent upon better buying, prices have been advancing. The improvement is not considered permanent, but the position is more encouraging.

Daily quotations are :—

Ordinary.—Thursday, £20 1s. 3d.; Friday, £19 18s. 9d.; Monday, £19 16s. 3d.; Tuesday, £19 12s. 6d.; Wednesday, £19 11s. 3d.

Lead.—The market for soft foreign pig continues quiet, but the price is firmly maintained. The world production of lead last year was 1,931,796 tons, compared with 1,847,000 tons in 1928.

The week's prices have been :—

Soft Foreign (Prompt).—Thursday, £21 12s. 6d.; Friday, £21 12s. 6d.; Monday, £21 12s. 6d.; Tuesday, £21 12s. 6d.; Wednesday, £21 10s.

Students' Corner.

Q.—What is the function of a denseners?

A.—The necessity for denseners is to overcome the uneven rate of cooling of thick and thin parts in close promixity. It is known, with cast iron, that the slower the rate of cooling, the larger will the crystals be, also when a thin section of metal is close to a thick section, the tendency is for the thin section, which freezes first, will be to draw away from the thick section, which is still liquid, and consequently leaving in that area a spongy, drawn place; this trouble can be ameliorated to some extent by the judicious application of denseners. Hence the function is an attempt to equalise solidification.

Q.—Of what material are denseners made?

A.—Denseners may be made of iron or steel (cast or wrought), or any other metal that is a good conductor of heat.

Q.—How does a densener equalise cooling from the liquid state to the solid state?

A.—The densener being made of metal is a good conductor of heat, when it is applied to a thick section of metal which is close to thin section of metal, by the densener being a transmitter of heat, the solidification of the thick section is accelerated, thus preventing the thin section drawing away from the thick section by equalising the cooling during that period.

Q.—Does equal cooling during the solidifying period always produce a sound casting?

A.—As a general rule it does, but there may be exceptions, such as large bodies of metal occur which involves a loss due to liquid shrinkage, this being rectified by the use of a feeding rod.

Q.—What guide is there for controlling the thickness of the densener and the part to be treated?

A.—*Experientia Docet.* If the densener is too large, there may be an undue hardening in the area where the densener has been applied. On the other hand, if the densener is not large, or sufficiently bulky, the liquid metal will remain fluid too long to prevent drawing.

Q.—What is the influence of the densener upon the molten metal that differs from the influence of sand?

A.—Metal is a good conductor of heat sand is a poor conductor of heat.

Q.—Are denseners always a success in producing a solid casting free from drawn places?

A.—Actually, it is very difficult in some cases to reach the spot required for the densener to be effective, especially is this so in the internal parts of some castings, where there exists hot spots, or super-heated areas. The cure for such needs to be considered separately.

XUM

Sterling

ALL STEEL TUBULAR

WHEELBARROWS

ARE IDEAL FOR ALL FOUNDRY PURPOSES.
THEY POSSESS MANY IMPORTANT ADVANTAGES.

Tray set well forward.
The load is on the Wheel.

Tray Reinforced with Stout Continuous Rod.
Broad Tyred 10-spoke Wheel.
Substantial Nose for forward dumping.
Strong Tubular Handles.
Patent Clipavoids perforating the Handle at point of strain.
Legs strongly braced cannot get shaky.

Pre-lubricated Axle-bearings. Never require oiling.

Legs bent square and fitted with renewable Shoes.

A Sterling Product designed for hard work and built to last.

All parts are standardised and interchangeable for repairs.

Capacities from 2½ to 6 cubic feet.

Write for Catalogue No. 37.

STERLING FOUNDRY SPECIALTIES LTD.

London Office:
13, VICTORIA STREET, S.W.1

BEDFORD.

Telephone: 3345 BEDFORD.
Telegrams: "STERFLASK, BEDFORD."
Code: WESTERN UNION.

WEEKLY PRICE CURRENT.

COPPER.

	£	s.	d.
Standard cash	72	17	6
Three months	69	5	0
Electrolytic	83	10	0
Tough	77	0	0
Best selected	77	10	0
Sheets	110	0	0
India	90	15	0
Wire bars	84	5	0
Do. Feb.	84	5	0
Do. March.	84	5	0
Ingot bars	84	5	0
H.C. wire rods	86	2	6
Off. av. cash, January	71	11	1 4/12
Do., 3 mths., January	69	0	2 1/12
Do., Sttlmnt., January	71	10	8 7/11
Do., Electro, January	83	10	9 6/11
Do., B.S., January	77	3	7 1/2
Do., wire bars, January	83	16	7 11/12
Aver. spot price, copper, Jan.	71	11	1 1/12
Solid drawn tubes			15d.
Brazed tubes			15d.
Wire			11½d.

BRASS.

Solid drawn tubes	12½d.
Brazed tubes	14½d.
Rods, drawn	12½d.
Rods, extd. or rlld.	7½d.
Sheets to 10 w.g.	11½d.
Wire	10½d.
Rolled metal	10½d.
Yellow metal rods	7½d.
Do. 4 × 4 Squares	8d.
Do. 4 × 3 Sheets	8½d.

TIN.

	£	s.	d.
Standard cash	176	17	6
Three months	179	17	6
English	178	0	0
Bars	179	10	0
Straits	178	10	0
Australian	177	15	0
Eastern	180	10	0
Banca	180	15	0
Off. av. cash, January	175	10	10 10/11
Do., 3 mths, January	178	15	2 5/11
Do., Sttlmt., January	175	10	5 5/11
Aver. spot, January	175	10	10 10/11

SPELTER.

	£	s.	d.
Ordinary	19	11	3
Remelted	18	5	0
Hard	16	5	0
Electro 99.9	21	15	0
English	20	0	0
India	18	0	0
Zinc dust (Nom.)	30	0	0
Zinc ashes	6	0	0
Off. aver., January	19	18	9
Aver., spot, January	19	12	8 1/12

LEAD.

	£	s.	d.
Soft foreign ppt.	21	10	0
English	23	0	0
Off. average, January	21	11	1 4/11
Average spot, January	21	10	10 10/11

ZINC SHEETS, &c.

	£	s.	d.
Zinc sheets, English	30	0	0
Do. V.M. ex-whf.	27	15	0
Rods	34	0	0
Boiler plates	26	10	0
Battery plates	27	0	0

ANTIMONY.

	£	s.	d.
Special brands, Eng.	46	10	0
Chinese	31	0	0
Crude	18	0	0

QUICKSILVER.

	£	s.	d.
Quicksilver	23	0	0

FERRO-ALLOYS AND STEEL-MAKING METALS.

	£	s.	d.
Ferro-silicon—			
25%	7	17	6
45/50%	11	10	0
75%	19	0	0
Ferro-vanadium—			
35/50%	12/9 lb. Va.		
Ferro-molybdenum—			
70/75% c. free	4/2 lb. Mo.		
Ferro-titanium—			
23/25% carbonless	9d. lb.		
Ferro-phosphorus, 20/25%	£16	0	0
Ferro-tungsten—			
80 85%, c. fr.	3/1½ lb.		
Tungsten metal powder—			
98/99%	3/4½ lb.		
Ferro-chrome—			
2/4% car.	£30	6	0
4/6% car.	£23	7	6
6/8% car.	£22	12	6
8/10% car.	£22	2	0
Ferro-chrome—			
Max. 2% car.	£33	12	6
Max. 1% car.	£39	0	0
Max. 0.70% car.	£41	12	6
70%, carbonless	11d. lb.		
Nickel—99% cubes, or pellets	£175	0	0
Ferro-cobalt	9/6 lb.		
Aluminium 98/99%	£95	0	0
Metallic chromium—			
96/98%	2/7 lb.		
Ferro-manganese (net)—			
76/80% loose	£12	10	0
76/80% packed	£13	10	0
76/80%, export	£12	15	0
Metallic manganese—			
94/96%, carbonless	1/4 lb.		

Per ton unless otherwise stated.

HIGH-SPEED TOOL STEEL.

Finished bars, 14% tungsten	£0	2	0
Finished bars, 18% tungsten	£0	2	9

Per lb. net, d/d buyers' works.

Extras—

Rounds and squares, 3 in. and over	4d. lb.
Rounds and squares, under ½ in. to ¼ in.	3d. lb.
Do., under ½ in. to 7/32 in.	1/- lb.
Flats, ½ in. × ¼ in. to under 1 in. × ⅛ in.	3d. lb.
Do., under ½ in. × ¼ in.	1/- lb.
Bevels of approved sizes and sections	6d. lb.

Bars cut to length, 10% extra.

SCRAP.

South Wales—	£	s.	d.		£	s.	d.
Heavy steel					3	7	6
Bundled steel and shrngs.	3	2	6	to	3	5	0
Mixed iron and steel	3	2	6	to	3	4	0
Heavy cast iron	2	18	6	to	3	0	0
Good machinery for foundries					3	2	6
Cleveland—							
Heavy steel					3	3	6
Steel turnings					2	16	6
Cast-iron borings					2	13	0
Heavy forge					3	15	0
W.I. piling scrap					3	10	0
Cast-iron scrap	3	2	6	to	3	6	6
Midlands—							
Ord. cast-iron scrap					3	5	0
Heavy wrought					3	17	6
Steel turnings	2	5	0	to	2	7	6
Scotland—							
Heavy steel					3	10	0
Cast-iron borings					2	10	0
Wrought-iron piling					3	18	6
Heavy machinery					3	10	0

London—Merchants' buying prices delivered yard.

	£	s.	d.
Copper (clean)	61	0	0
Brass	43	0	0
Lead (less usual draft)	20	0	0
Tea lead	16	0	0
Zinc	13	0	0
New aluminium cuttings	65	0	0
Braziery copper	57	0	0
Gunmetal	54	0	0
Hollow pewter	130	0	0
Shaped black pewter	97	0	0

PIG-IRON.

(f.o.t. unless otherwise stated.)

N.E. Coast—	
Foundry No. 1	75/-
Foundry No. 3	72/6
Foundry No. 4	71/6
Forge No. 4	71/-
Hematite No. 1	78/6
Hematite M/Nos.	78/-
N.W. Coast—	
Hem. M/Nos. d/d Glas.	86/-
„ d/d Birm.	95/6
Midlands—	
Staffs. common*	—
„ No. 4 forge*	74/6
„ No. 3 fdry.*	78/6
Shrops. basic	—
„ Cold blast, ord.	—
„ roll iron	—
Northants forge*	71/-
„ fdry. No. 3*	75/-
Derbyshire forge*	74/6
„ fdry. No. 3*	78/6
„ basic*	—

*d/d Black Country dist.

Scotland—	
Foundry No. 1	80/6
„ No. 3	78/-
Hem. M/Nos.	81/-
Sheffield (d/d district)—	
Derby forge	69/6
„ fdry. No. 3	73/6
Lincs. forge.	73/6
„ fdry No. 3	77/6
E.C. hematite	89/-
W.C. hematite	91/6
Lincs. (at furnaces)—	
Forge No. 4	—
Foundry No. 3	—
Basic	—
Lancashire (d/d eq. Man.)—	
Derby forge	—
„ fdry. No. 3	77/-
Northants foundry No. 3	—
Dalzell, No. 3 (special)	105/- to 107/6
Summerlee, No. 3	95/-
Glengarnock, No. 3	—
Gartsherrie, No. 3	95/-
Monkland, No. 3	95/-
Shotts, No. 3	95/-

FINISHED IRON AND STEEL.

Usual District deliveries for iron; delivered consumers' station for steel.

Iron—	£	s.	d.		£	s.	d.
Bars (cr.) nom.					10	15	0
Nut and bolt iron	9	2	6	to	9	7	6
Hoops	10	15	0	to	11	5	0
Marked bars (Staffs) f.o t.					12	10	0
Gas strip	10	15	0	to	11	5	0
Bolts and nuts, ¾ in. × 4 in.					15	5	0
Steel—							
Ship plates	8	15	0	to	8	17	6
Boiler plts.	9	15	0	to	10	10	0
Chequer plts.					10	12	6
Angles					8	7	6
Tees					9	7	6
Joists					8	10	0
Rounds and squares, 3 in. to 5½ in.					9	7	6
Rounds under 3 in. to ¾ in. (Untested)					8	2	6

and upwards

Flats—8 in. wide and over	8	12	6
„ under 8 in. and over 5 in.	8	17	6
Rails, heavy	8	10	0
Fishplates	12	10	0
Hoops (Staffs) 9 10 0 to 9	15	0	
Black sheets, 24 g.	9	15	0
Galv.cor.shts., 24g. 11 15 0 to 12	0	0	
Galv. fencing wire, 8g. plain	12	0	0
Billets, soft 6 2 6 to 6	12	6	
Billets, hard 7 10 0 to 8	0	0	
Sheet bars 5 17 6 to 6	5	0	
Tin bars 5 17 6 to 6	5	0	

PHOSPHOR BRONZE.

	Per lb. basis.
Strip	1/4
Sheet to 10 w.g.	1/5
Wire	1/6
Rods	1/5
Tubes	1/9¼
Castings	1/4

Delivery 3 cwt. free.
10% phos. cop. £40 above B.S.
15% phos. cop. £50 above B.S.
Phosphor tin (5%) £30 above price of English ingots.
C. Clifford & Son, Limited.

NICKEL SILVER, &c.

	per lb.
Ingots for raising	10d. to 1/4
Rolled—	
To 9 in. wide	1/4 to 1/10
To 12 in. wide	1/4½ to 1/10½
To 15 in. wide	1/4½ to 1/10½
To 18 in. wide	1/5 to 1/11
To 21 in. wide	1/5½ to 1/11½
To 25 in. wide	1/6 to 2/-
Ingots for spoons and forks	10d. to 1/6½
Ingots rolled to spoon size	1/1 to 1/9½
Wire round—	
3/0 to 10 G.	1/7½ to 2/2½

with extras according to gauge.

AMERICAN IRON AND STEEL.

At Pittsburgh unless otherwise stated.

	Dols.
No. 2X foundry, Phila.	20.76
No. 2 foundry, Valley	18 50
No. 2 foundry, Birm.	14.50
Basic	20.26
Bessemer	20.76
Malleable	20.76
Grey forge	19.76
Ferro-mang. 80% d/d	105.00
O.-h. rails, h'y, at mill	43.00
Bessemer billets	35.00
O.-h. billets	35.00
O.-h. sheet bars	35.00
Wire rods	40.00
	Cents.
Iron bars, Phila.	2.12
Steel bars	1.90
Tank plates	1.80
Beams, etc.	1.90
Skelp, grooved steel	1.85
Skelp, sheared steel	1.85
Steel hoops	2.20
Sheets, black, No. 24	2.60
Sheets, galv., No. 24	3.30
Sheets, blue an'l'd, No. 13	2.25
Wire nails	2.30
Plain wire	2.40
Barbed wire, galv.	2.95
Tinplates, 100-lb. box	$5.25

COKE (at ovens).

Welsh foundry	32/- to 37/-
„ furnace	29/- to 32/-
Durham and Northumberland—	
„ foundry	17/- to 17/6
„ furnace	19/- to 19/6
Midlands, foundry	—
„ furnace	—

TINPLATES.

f.o.b. Bristol Channel ports.

I.C. cokes	20×14 box	18/9
„	28×20 „	37/-
„	20×10 „	26/6
„	18¾×14 „	19/3
C.W.	20×14 „	16/-
„	28×20 „	34/3
„	20×10 „	23/6
„	18¾×14 „	17/-
Terneplates	28×20	32/6 per box basis f.o.b.

SWEDISH CHARCOAL IRON & STEEL.

Pig-iron	£6	0	0	to	£7	10	0
Bars, hammered, basis	£17	10	0	to	£18	10	0
Bars and nail-rods, rolled, basis	£15	17	6	to	£16	15	0
Blooms	£10	0	0	to	£12	0	0
Keg steel	£32	0	0	to	£33	0	0
Faggot steel	£20	0	0	to	£24	0	0
Bars and rods dead soft, steel	£11	0	0	to	£14	0	0

All per English ton, f.o.b. Gothenburg.

TUBES AND FITTINGS.

Over ½ in. up to 6 in.

	Tubes.	*Fittings:*
Gas	65% ..	47½%
Water	61½% ..	42½%
Steam	57½% ..	37½%

W.I. 10% extra.

DAILY FLUCTUATIONS.

Standard Copper (cash).

			£	s.	d.	
Jan.	30	..	72	0	0	inc. 3/9
,,	31	..	71	17	6	dec. 2/6
Feb.	3	..	72	7	6	inc. 10/–
,,	4	..	72	15	0	,, 7 6
,,	5	..	72	17	6	,, 2/6

Electrolytic Copper.

			£	s.	d.			
Jan.	30	..	83	10	0	No	change	
,,	31	..	83	10	0	,,	,,	
Feb.	3	..	83	10	0	,,	,,	
,,	4	..	83	10	0	,,	,,	
,,	5	..	83	10	0	,,	,,	

Standard Tin (cash).

			£	s.	d.		
Jan.	30	..	178	0	0	dec.	50/–
,,	31	..	176	12	6	,,	27/6
Feb.	3	..	174	15	0	,,	37/6
,,	4	..	176	15	0	inc.	40/–
,,	5	..	176	17	6	,,	2/6

Tin (English ingots).

			£	s.	d.			
Jan.	30	..	179	0	0	dec.	60/–	
,,	31	..	177	15	0	,,	25/–	
Feb.	3	..	175	15	0	,,	40/–	
,,	4	..	177	10	0	inc.	35/–	
,,	5	..	178	0	0	,,	10/–	

Zinc Sheets (English).

			£	s.	d.			
Jan.	30	..	30	0	0	No	change	
,,	31	..	30	0	0	,,	,,	
Feb.	3	..	30	0	0	,,	,,	
,,	4	..	30	0	0	,,	,,	
,,	5	..	30	0	0	,,	,,	

Spelter (ordinary).

			£	s.	d.		
Jan.	30	..	20	1	3	No	change
,,	31	..	19	18	9	dec.	2/6
Feb.	3	..	19	16	3	,,	2/6
,,	4	..	19	12	6	,,	3/9
,,	5	..	19	11	3	,,	1/3

Lead (English).

			£	s.	d.		
Jan.	30	..	23	0	0	No	change
,,	31	..	23	0	0	,,	,,
Feb.	3	..	23	0	0	,,	,,
,,	4	..	23	0	0	,,	,,
,,	5	..	23	0	0	,,	,,

AVERAGE MONTHLY PRICES OF STEEL RAILS.

Year.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly average.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
1908	6 2 6	6 0 0	6 0 0	5 15 6	5 15 0	5 15 0	5 15 0	5 15 0	5 15 0	5 15 0	5 15 0	5 10 0	5 16 3
1909	5 5 0	5 5 0	5 5 0	5 0 0	5 5 0	5 5 0	5 5 0	5 5 0	5 5 0	5 5 0	5 5 0	5 5 0	5 5 0
1910	5 5 0	5 7 6	5 7 6	5 7 6	5 10 0	5 10 0	5 10 0	5 10 0	5 10 0	5 10 0	5 10 0	5 10 0	5 8 11½
1911	5 15 0	5 15 0	5 15 0	5 12 6	5 12 6	5 12 6	5 12 6	5 12 6	5 12 6	5 12 6	5 12 6	5 12 6	5 13 1½
1912	5 13 1	5 15 0	5 15 0	5 15 7	6 1 6	6 6 3	6 7 6	6 8 0	6 11 3	6 12 6	6 12 6	6 13 9	6 4 4
1913	6 15 0	6 14 4½	6 12 6	6 12 6	6 12 6	6 12 6	6 12 6	6 12 6	6 10 0	6 10 0	6 10 0	6 10 0	6 12 0
1914	6 10 0	6 10 0	6 6 3	6 0 0	6 0 0	6 0 0	5 14 0	6 2 6	6 13 9	6 12 0	6 7 6	6 7 6	6 5 3½
1915	6 10 6	6 17 6	7 5 0	7 12 6	7 12 6	7 17 6	8 17 6	9 2 6	9 2 6	9 2 6	9 7 6	10 10 6	8 6 6½
1916	10 19 4	11 0 0	11 0 0	10 18 9	10 17 6	10 17 6	10 17 6	10 17 6	10 17 6	10 17 6	10 17 6	10 17 6	10 9 10
1917	10 17 6	10 17 6	10 17 6	10 17 6	10 17 6	10 17 6	10 17 6	10 17 6	10 17 6	10 17 6	10 17 6	10 17 6	10 17 6
1918	10 17 6	10 17 6	10 17 6	10 17 6	10 17 6	10 17 6	10 17 6	10 17 6	10 17 6	10 17 6	10 17 6	10 17 6	10 17 6
1919	10 17 6	13 7 6	13 7 6	13 7 6	15 0 0	15 10 0	16 0 0	16 10 0	16 10 0	16 10 0	16 10 0	17 5 0	14 12 11
1920	18 15 0	19 5 0	20 7 6	22 0 0	23 0 0	23 0 0	24 0 0	25 0 0	25 0 0	25 0 0	25 0 0	25 0 0	22 18 11½
1921	23 5 0	20 4 0	18 0 0	17 0 0	15 0 0	15 0 0	14 0 0	14 0 0	14 0 0	11 12 6	10 10 0	10 0 0	15 4 3
1922	9 10 0	9 10 0	9 10 0	9 10 0	9 10 0	9 10 0	9 10 0	9 0 0	8 15 0	8 15 0	8 15 0	8 15 0	9 4 2
1923	8 17 6	9 2 0	10 5 0	10 10 0	10 10 0	10 10 0	9 15 0	9 0 0	8 15 0	8 15 0	8 19 0	9 5 0	9 9 10
1924	9 5 0	9 5 0	9 5 0	9 5 0	9 5 0	9 2 6	9 0 0	9 0 0	9 0 0	9 0 0	9 0 0	9 0 0	9 2 3½
1925	9 0 0	9 0 0	9 0 0	9 0 0	8 15 0	8 10 7½	8 10 0	8 10 0	8 10 0	8 4 0	8 0 0	8 0 0	8 11 7½
1926	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 7 6	8 10 0	8 10 0	8 10 0	8 10 0	8 3 11½
1927	8 10 0	8 10 0	8 10 0	8 2 6	8 2 6	8 2 6	8 2 6	8 2 6	8 2 6	8 3 0	8 5 0	8 5 0	8 4 10
1928	8 5 0	8 5 0	8 5 9	8 6 3	8 6 3	8 6 3	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 7 9½
1929	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0
1930	8 10 0	—	—	—	—	—	—	—	—	—	—	—	—

AVERAGE MONTHLY PRICES OF EAST COAST HEMATITE AT MIDDLESBROUGH.

Year.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average.
	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
1915	83 11	88 6	94 8	107 0	102 6	101 3	98 9	98 7½	96 6	104 0	124 1	130 0	106 11½
1916	133 9	140 0	136 6	122 6	122 6	122 6	122 6	122 6	122 6	122 6	122 6	122 6	128 1½
1917	122 6	122 6	122 6	122 6	122 6	122 6	122 6	122 6	122 6	122 6	122 6	122 6	122 6
1918	122 6	122 6	122 6	122 6	122 6	122 6	122 6	122 6	122 6	122 6	122 6	122 6	122 6
1919	122 6	122 6	122 6	122 6	179 2	190 0	197 6	200 0	200 0	200 0	200 0	200 0	171 4
1920	220 0	220 0	240 0	260 0	260 0	260 0	260 0	260 0	260 0	260 0	260 0	260 0	251 8
1921	240 0	220 0	180 0	180 0	180 0	160 0	160 0	160 0	137 0	127 6	117 6	104 6	162 2
1922	97 6	91 7½	100 0	98 6	97 1½	94 7	93 6	90 9	89 7	91 10½	93 0	93 2	94 5½
1923	94 6	104 9	122 0	126 10½	122 0	115 3	107 0	98 8½	98 10½	99 1½	100 6½	102 3	107 10½
1924	102 4½	101 3	99 7½	99 0	98 9½	97 4½	95 3½	93 1½	90 7½	88 0	88 4½	88 5	95 2½
1925	87 5	85 9	84 7½	82 6	80 10½	79 3	77 1½	75 7½	75 0	74 3½	74 9	76 0	79 5½
1926	77 3	77 9	77 3½	76 3	77 4½	78 0	79 8½	81 9	83 4½	87 7½	92 6	90 5½	81 7½
1927	90 0	90 0	86 3½	83 1½	80 6	78 0	76 6	75 4½	75 0	72 9	71 9	71 1½	79 2½
1928	69 7½	69 7½	69 9	70 0	70 0	69 3	68 7½	69 2	70 0	70 0	70 3	71 0	69 9½
1929	71 6	72 0	73 6	74 0	74 0	74 1½	74 9	75 6	76 1½	76 8½	78 1½	79 0	74 11½
1930	78 2½	—	—	—	—	—	—	—	—	—	—	—	—

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